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United States Patent [19]

Carmein

[11] Patent Number: 5,980,256

[45] Date of Patent: *Nov. 9, 1999

[54] VIRTUAL REALITY SYSTEM WITH ENHANCED SENSORY APPARATUS

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[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: 08/600,893

[22] Filed: Feb. 13, 1996

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/401,550, Mar. 10, 1995, Pat. No. 5,562,572, and a continuation-in-part of application No. 08/145,413, Oct. 29, 1993, Pat. No. 5,490,784.

[51] Int. Cl.^{6} G09B 9/00

[52] U.S. Cl. .... 434/55; 434/29; 434/307 R; 434/365; 482/902

[58] Field of Search .... 434/29, 30, 34, 434/35, 37, 38, 40, 43, 45, 55, 58, 59, 62, 69, 118, 247, 307 R, 308, 365, 372; 482/1–9, 71, 72, 52, 54, 55, 57, 900–903; 472/2, 17, 60, 132; 73/379.01, 299, 323; 463/1, 36; 345/157, 179, 302, 473, 8; 414/4, 5; 348/121; 198/370.01–370.03, 779, 371.01–371.03, 840

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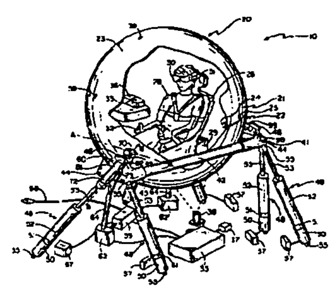
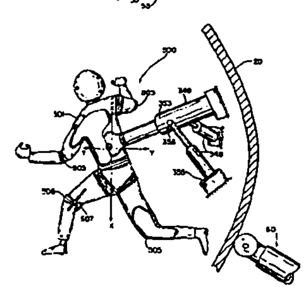
Primary Examiner—Joe H. Cheng
Attorney, Agent, or Firm—Fredrikson & Byron, PA

[57] **ABSTRACT**

The invention provides a motion simulating device which provides the user with full freedom of motion. Ideally, the motion is coordinated with the user's senses. The motion simulating device may include a generally spherical capsule supported by a number of rollers, at least one of which is a multi-directional active roller which frictionally engages the spherical capsule. This causes the spherical capsule to rotate in any desired direction. The capsule may have mounted within it an interactive solid, which may take the form of an omni-directional treadmill for supporting the user.

28 Claims, 37 Drawing Sheets





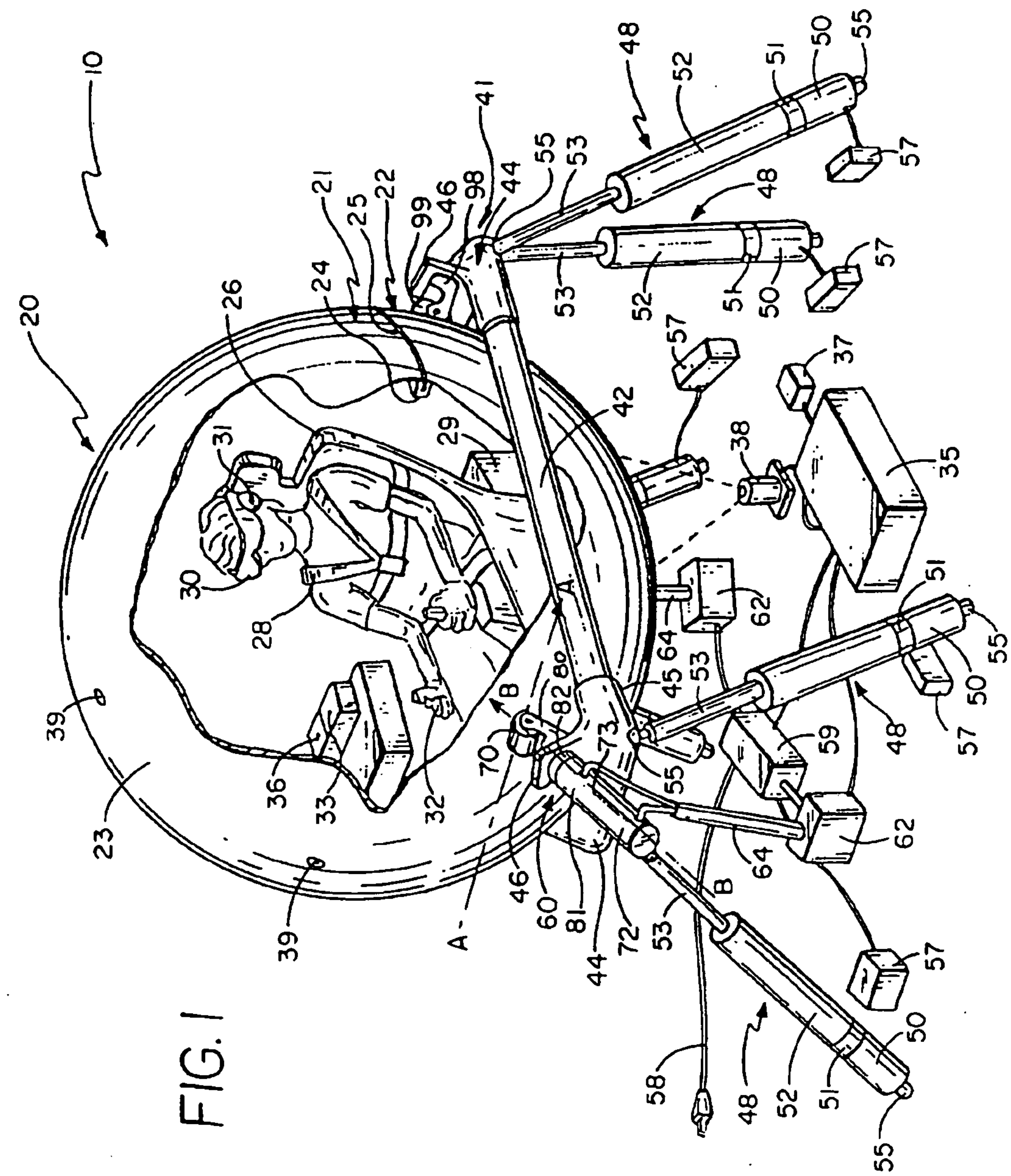


FIG. 1

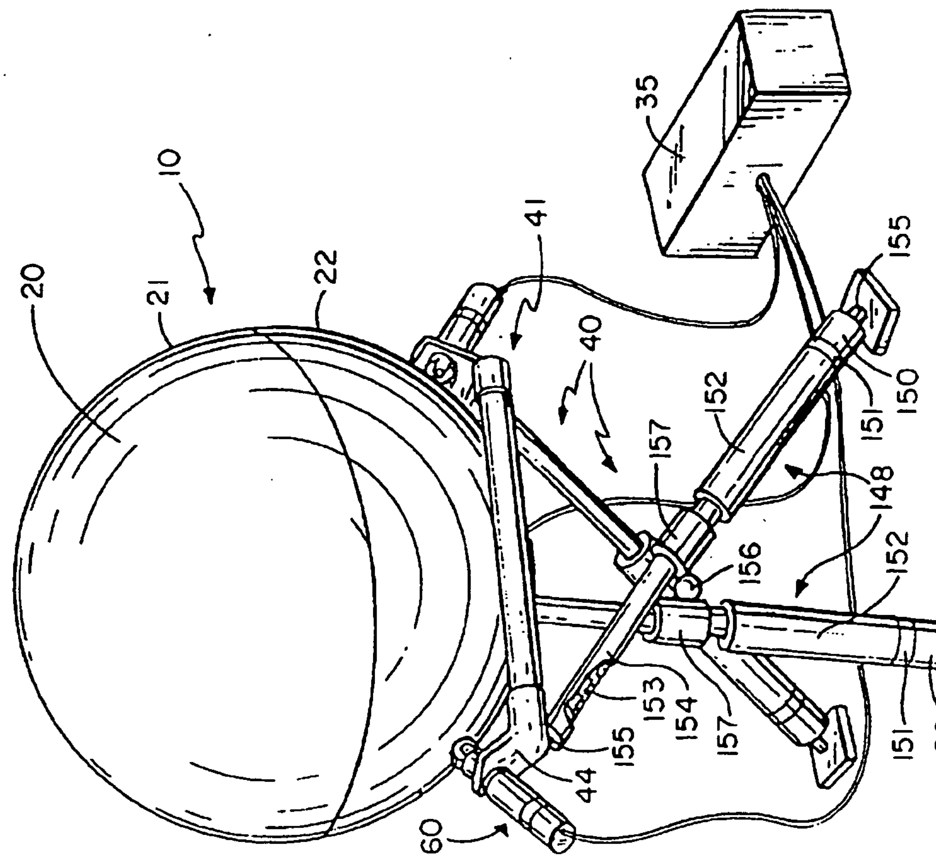


FIG. 2

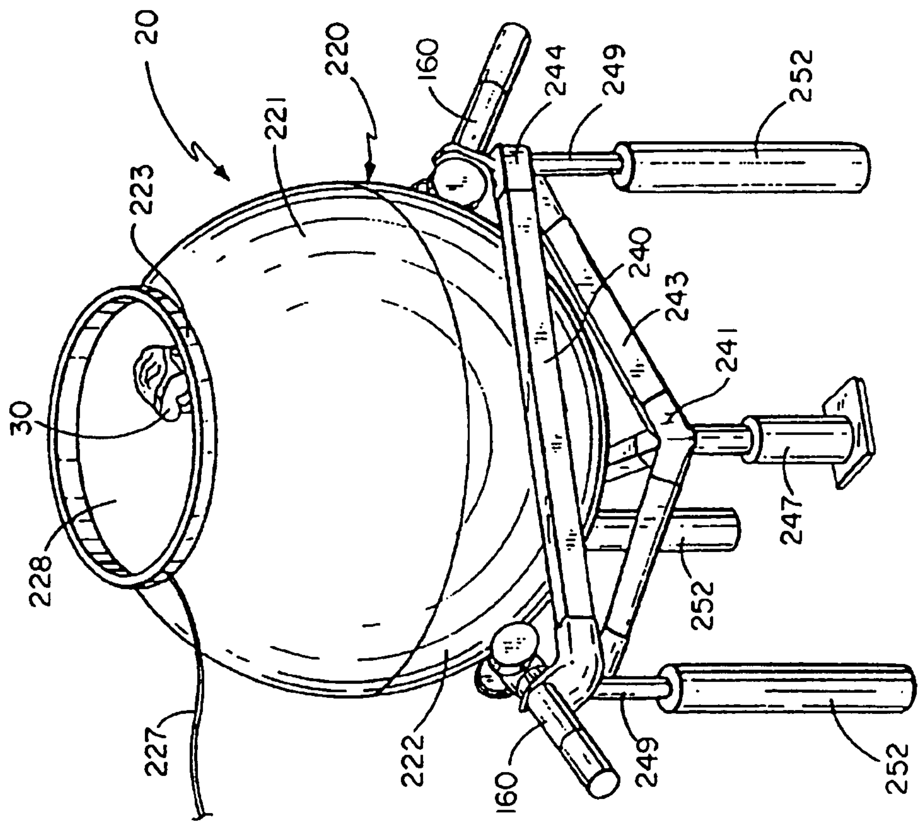

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FIG. 3

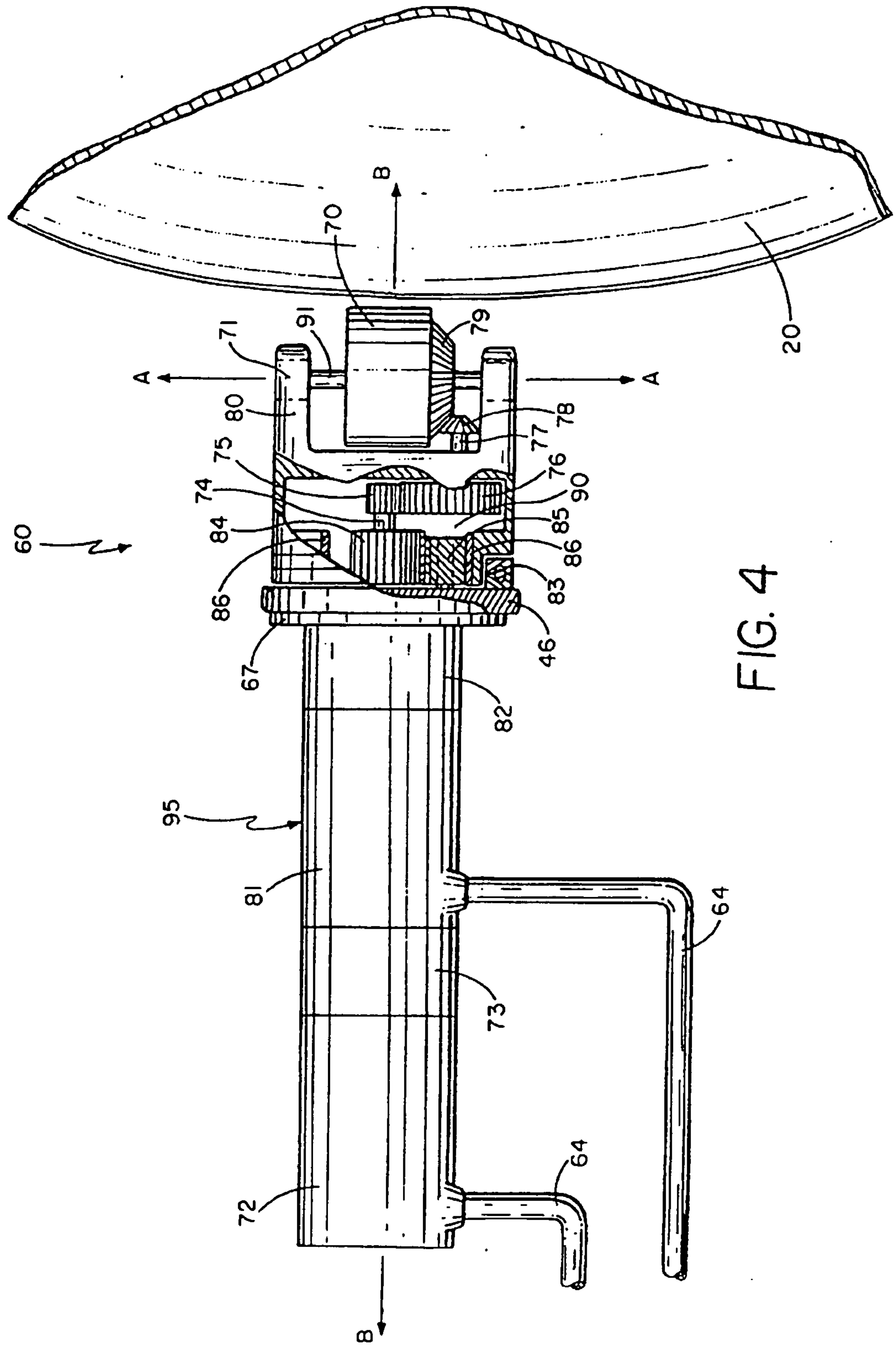
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FIG. 4

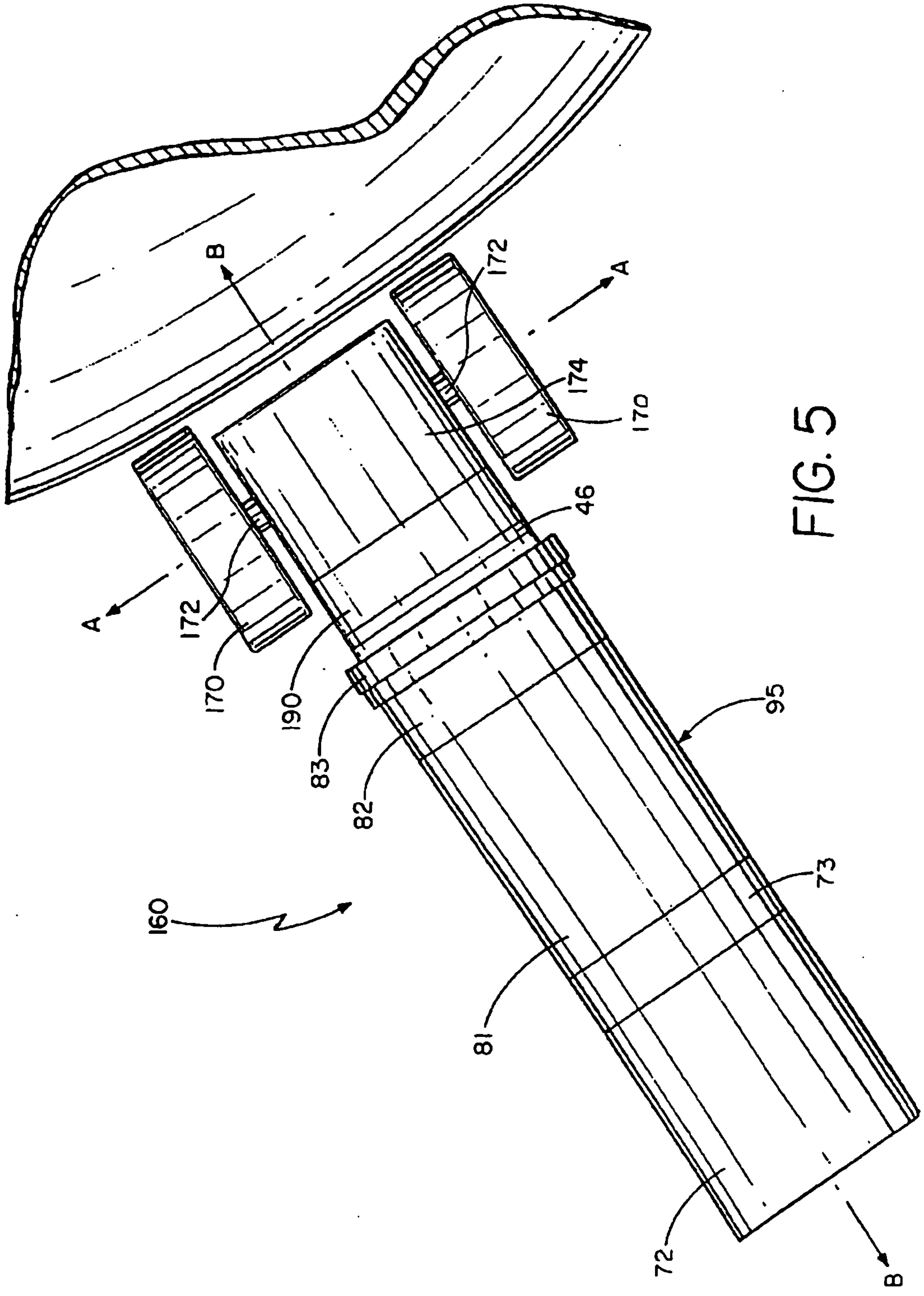

FIG. 5

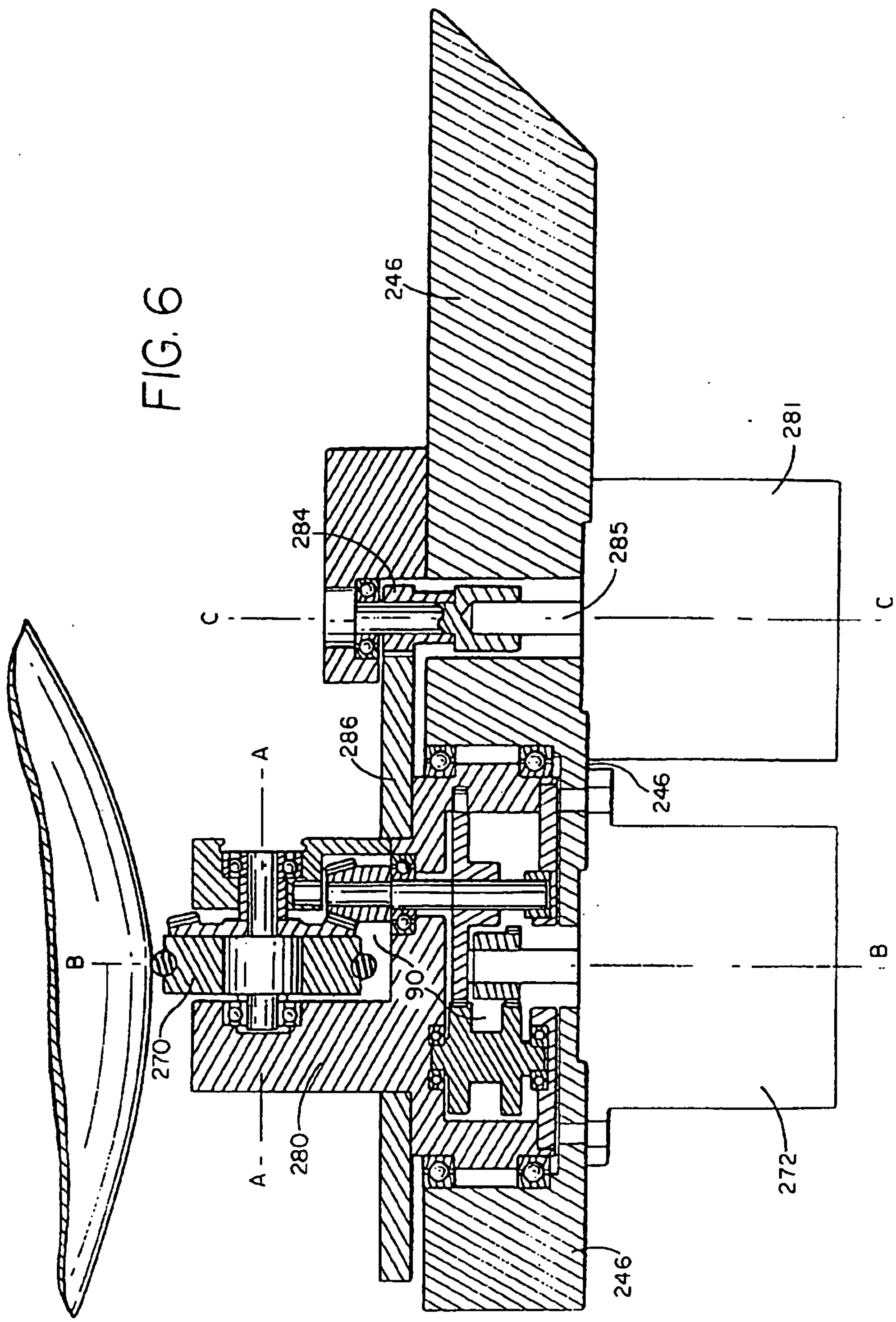

FIG. 6

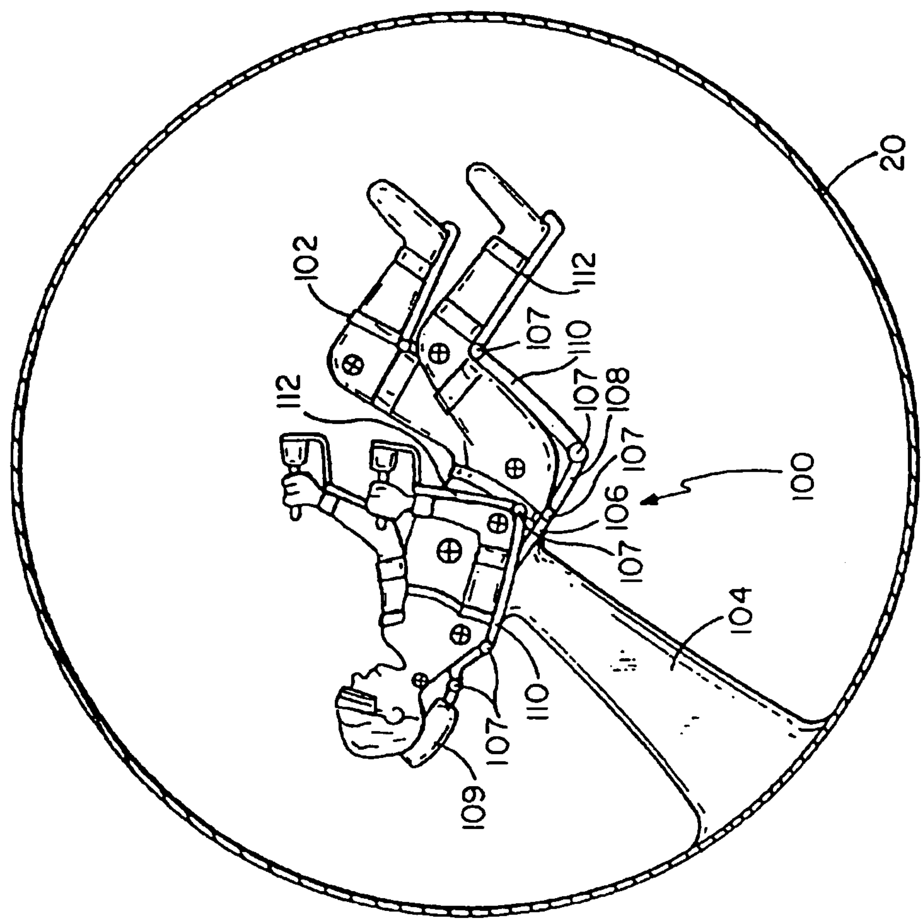

FIG. 7

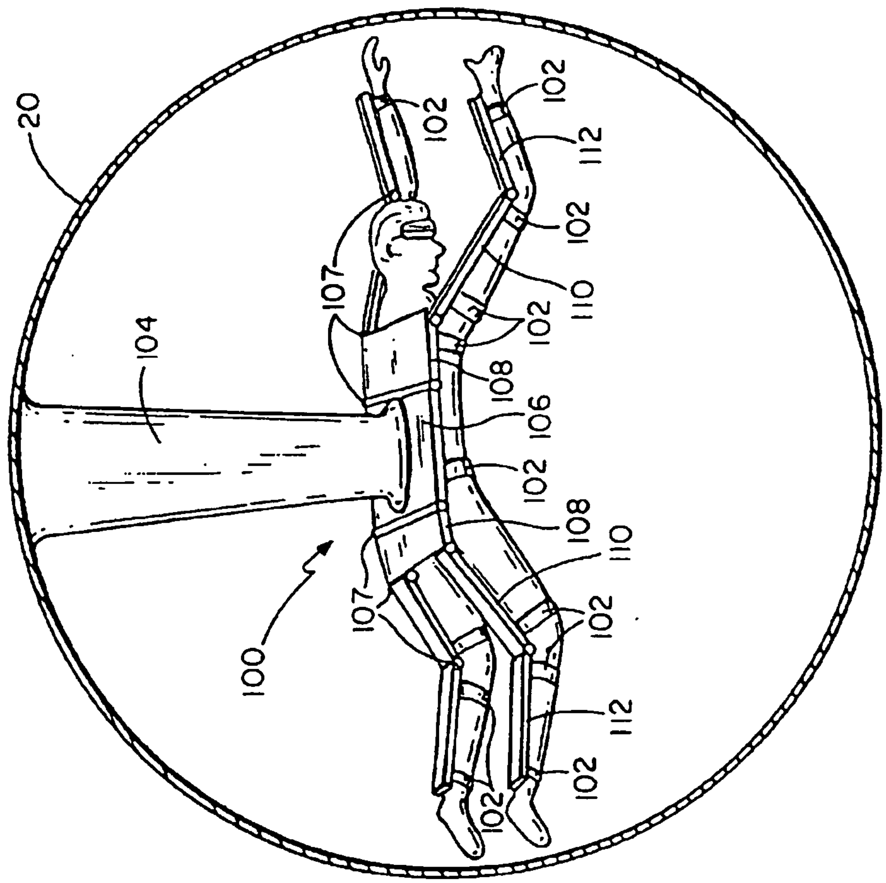

FIG. 8

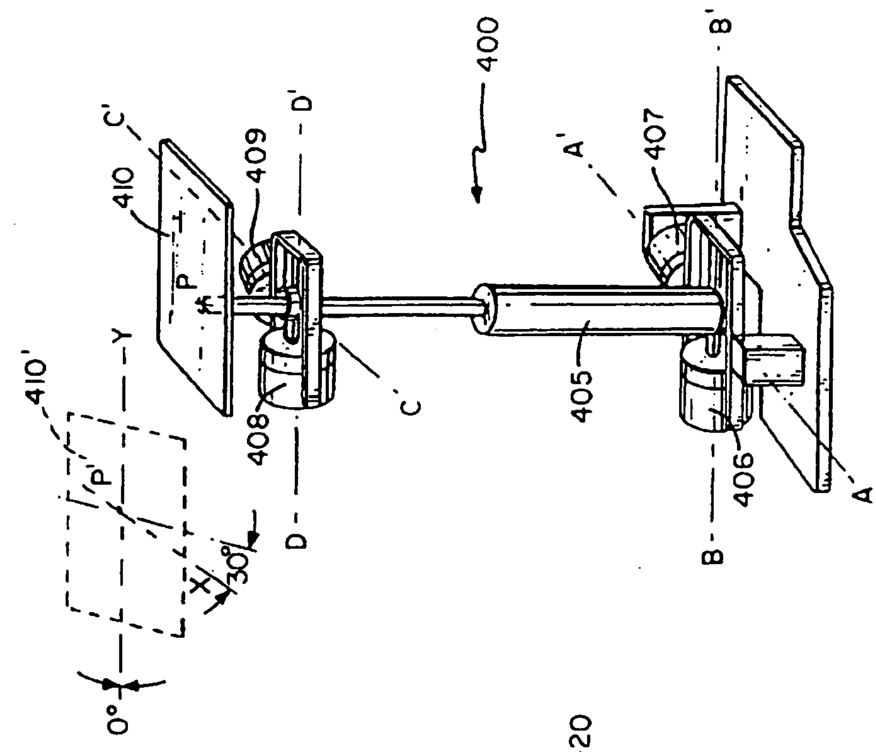
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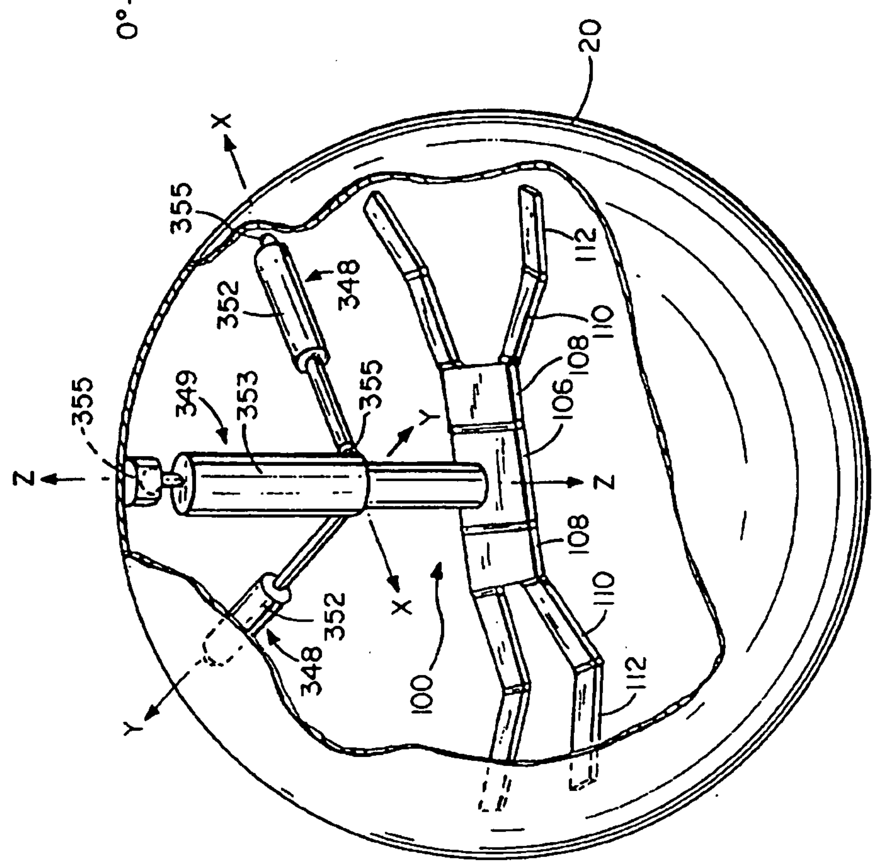
FIG. 12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112
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FIG. 9

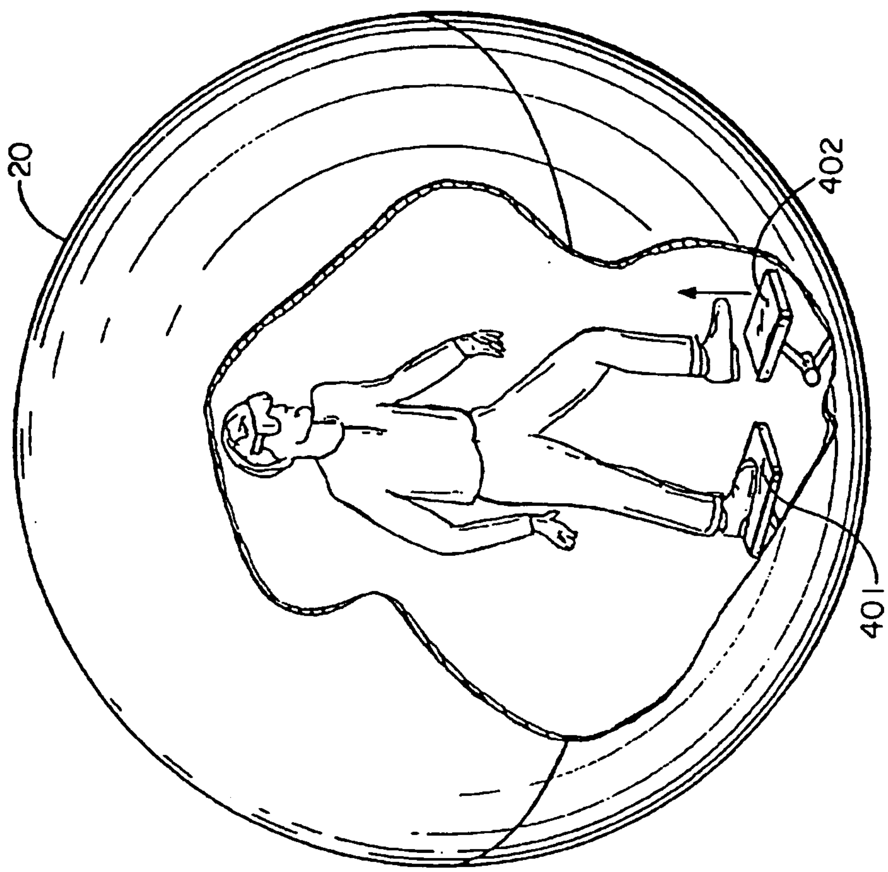
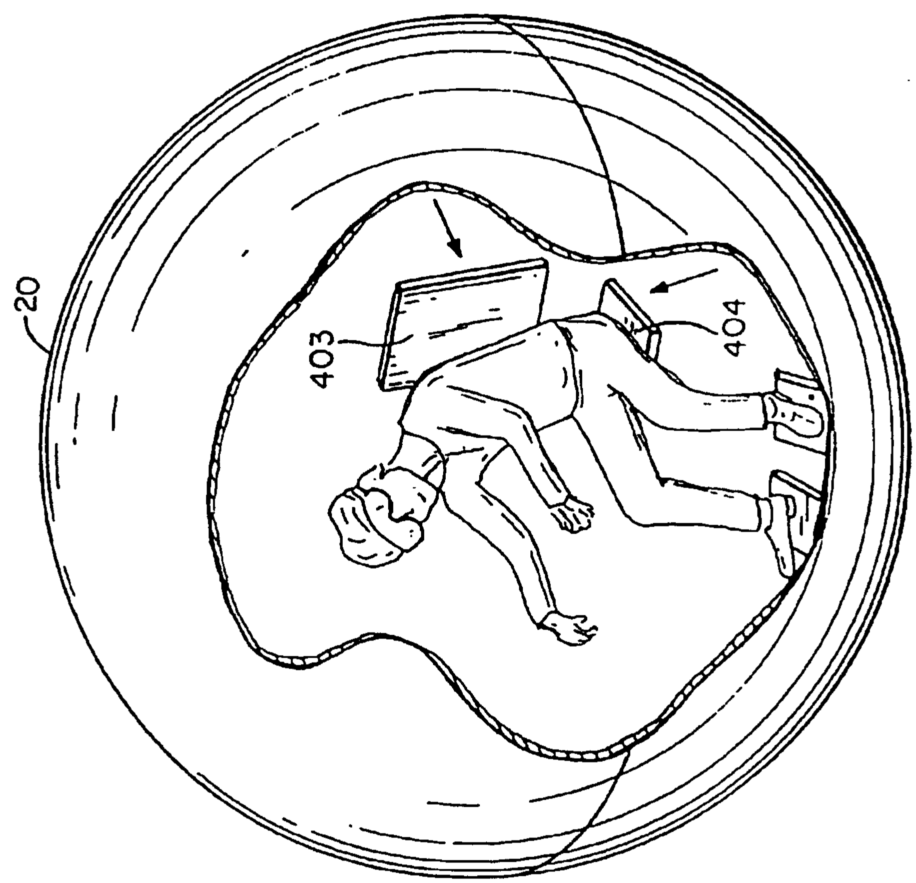


FIG. 10



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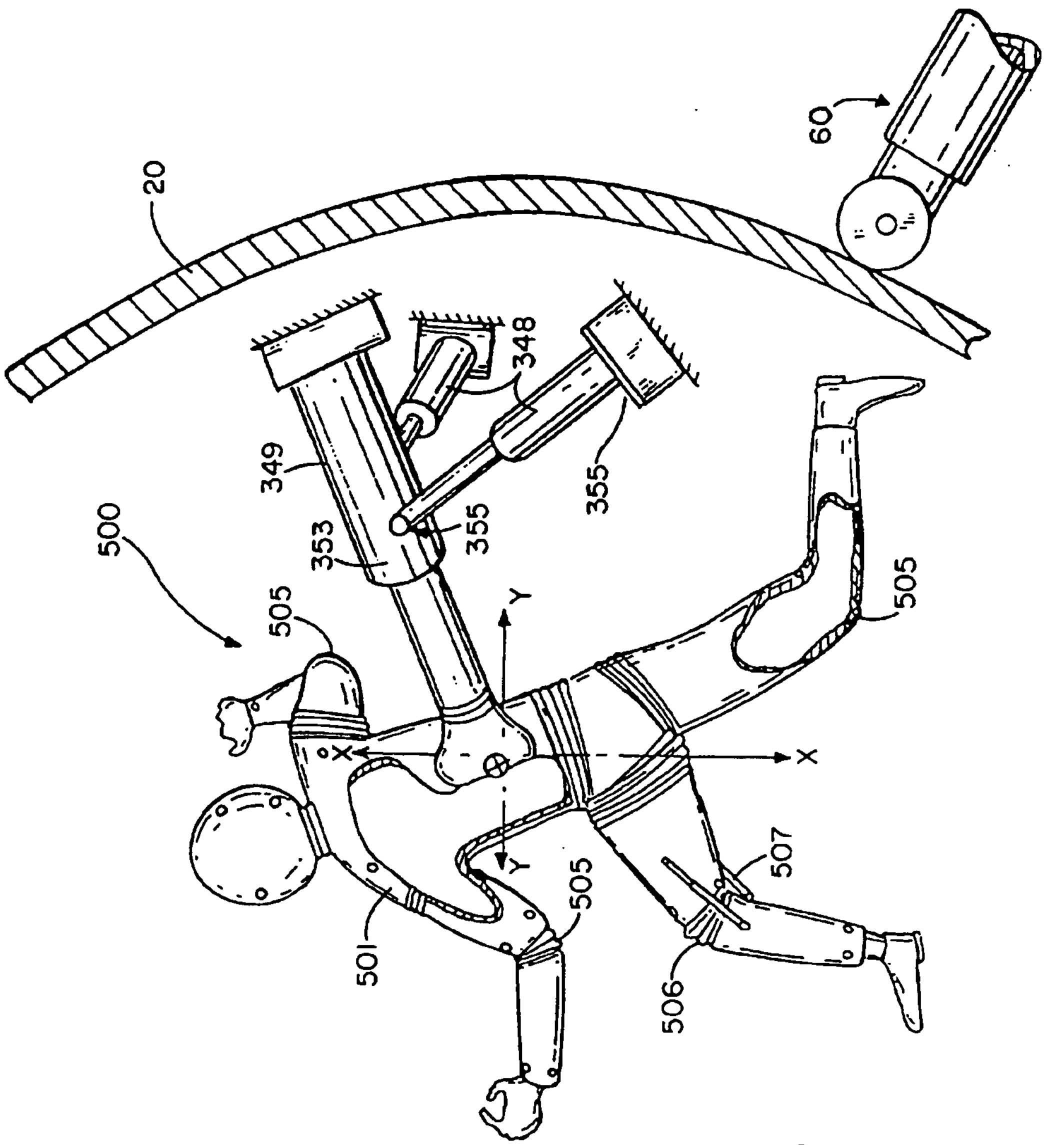

FIG. 13

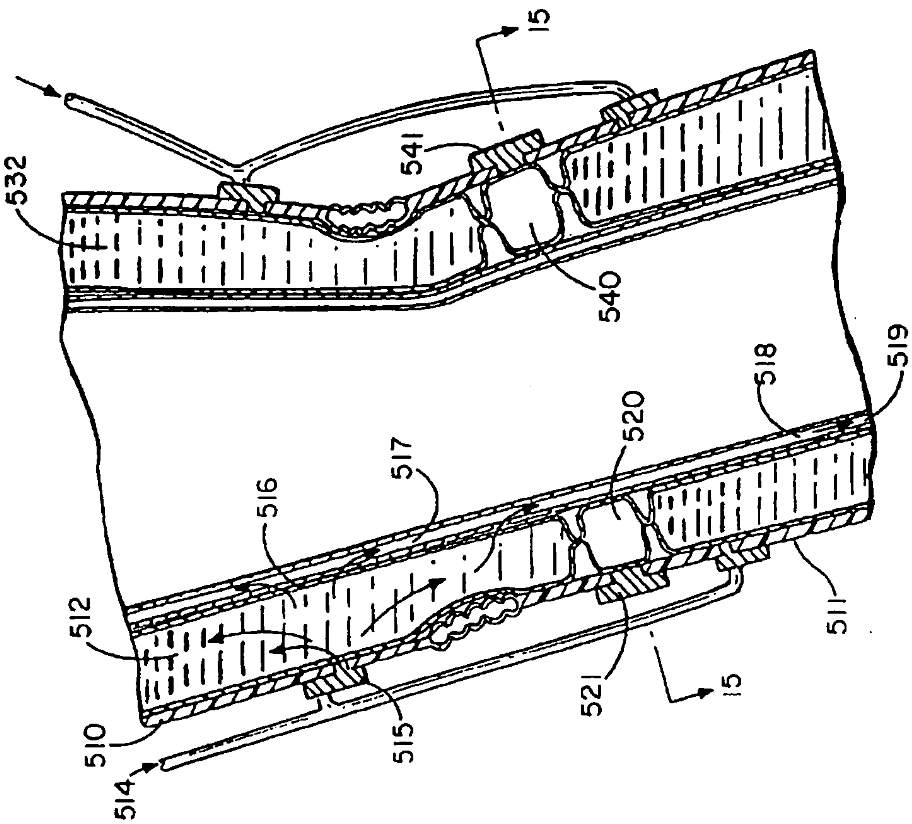

FIG. 14

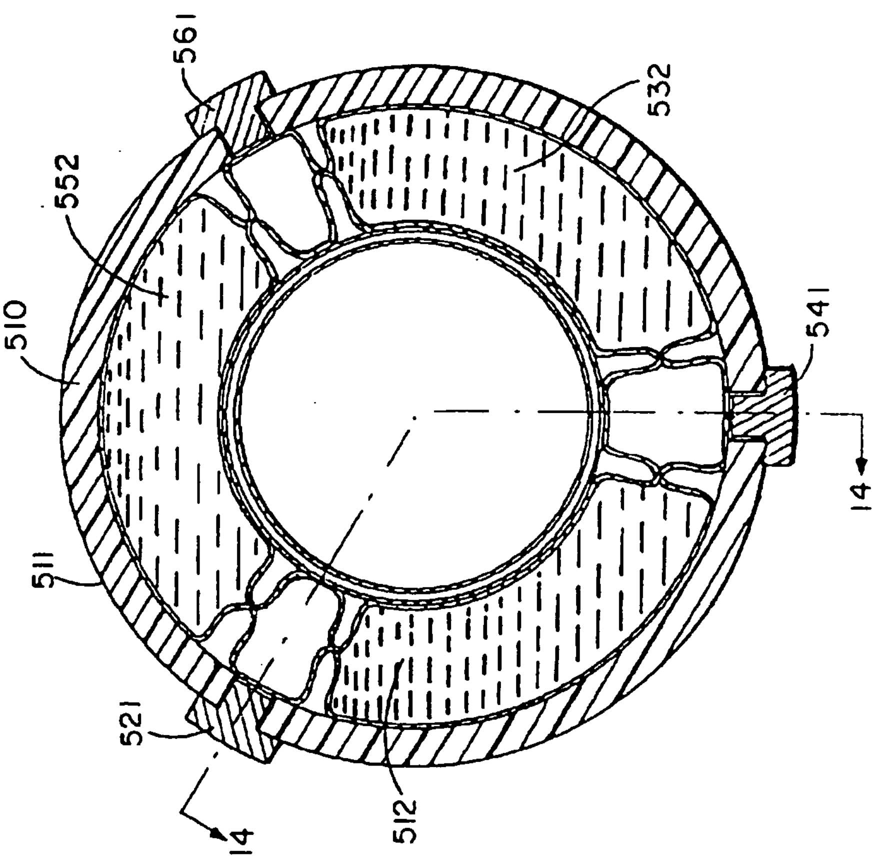

FIG. 15

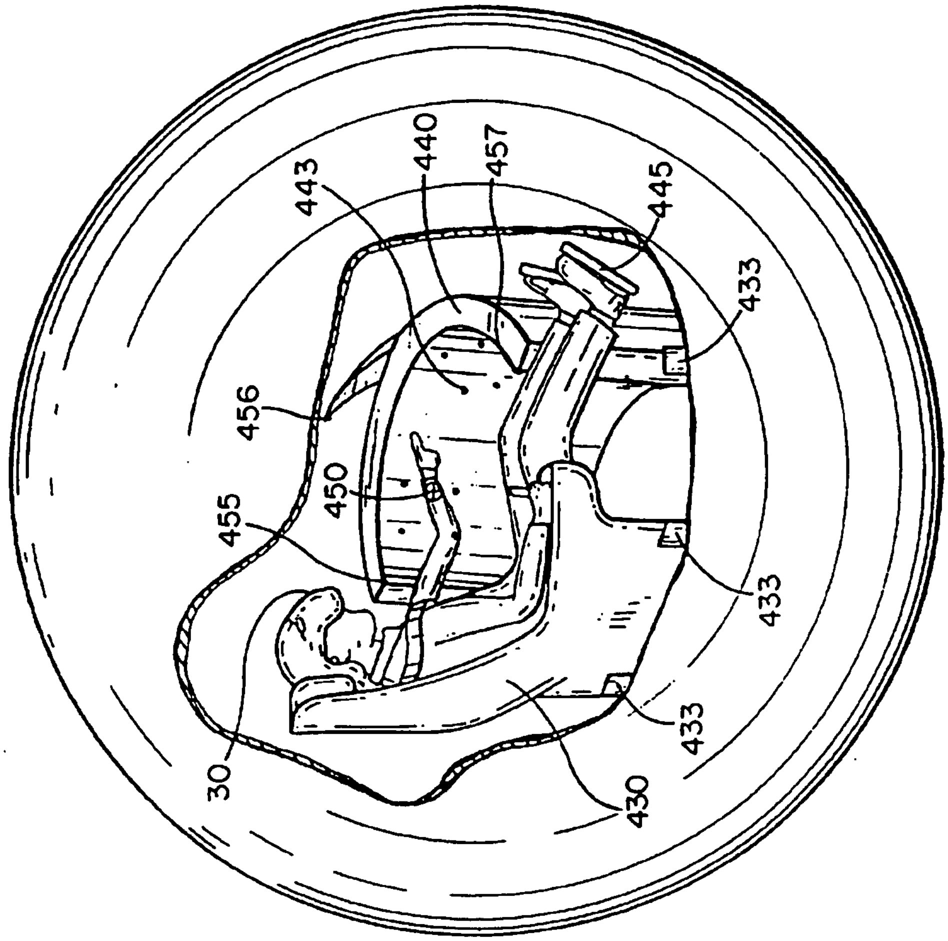

FIG. 16

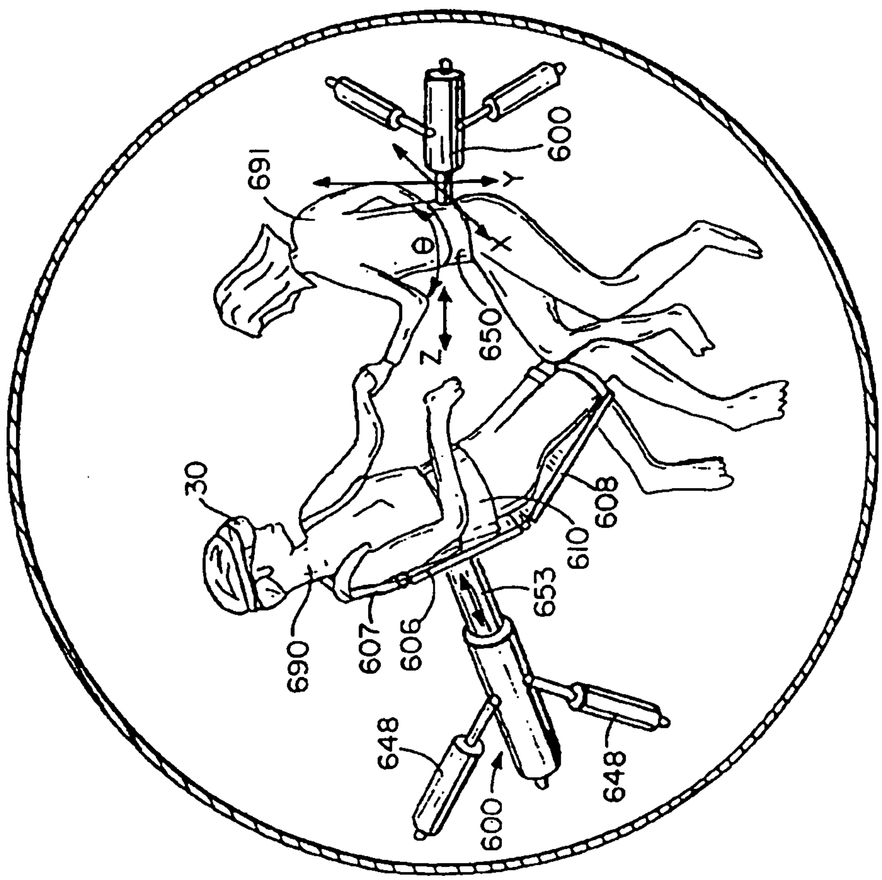

FIG. 17

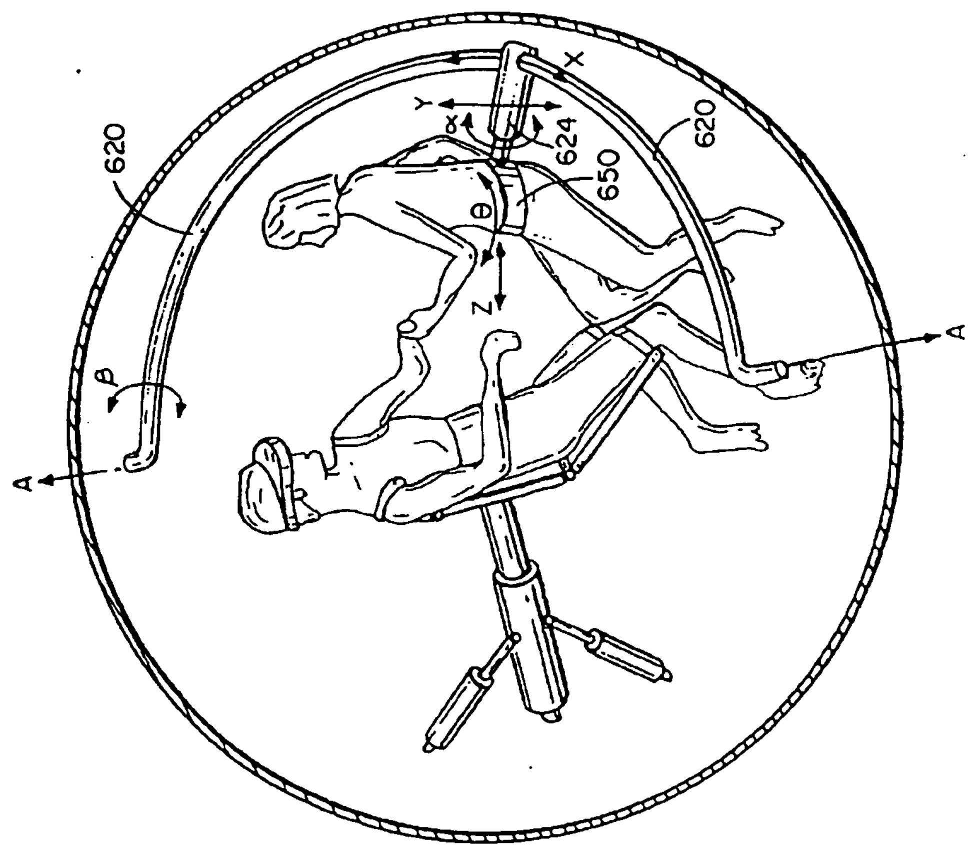

FIG. 18

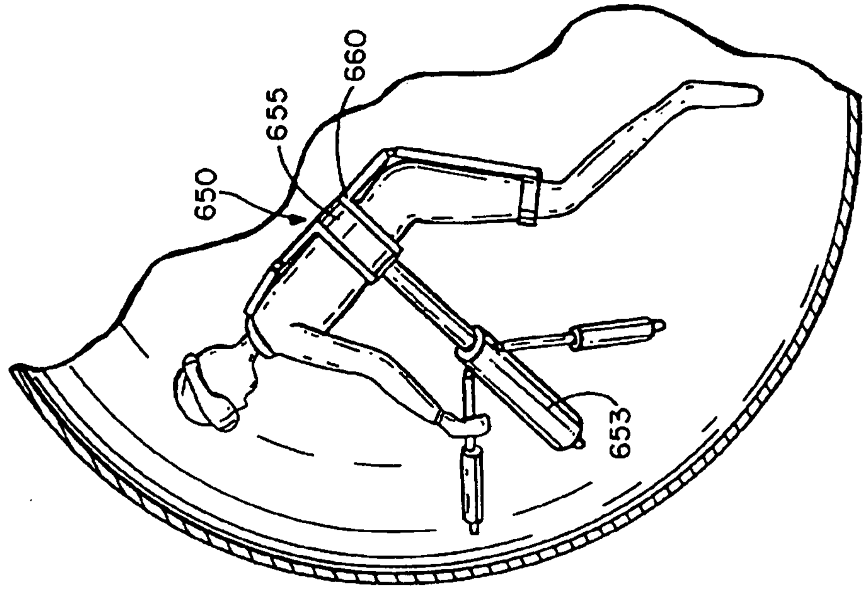

FIG. 19B

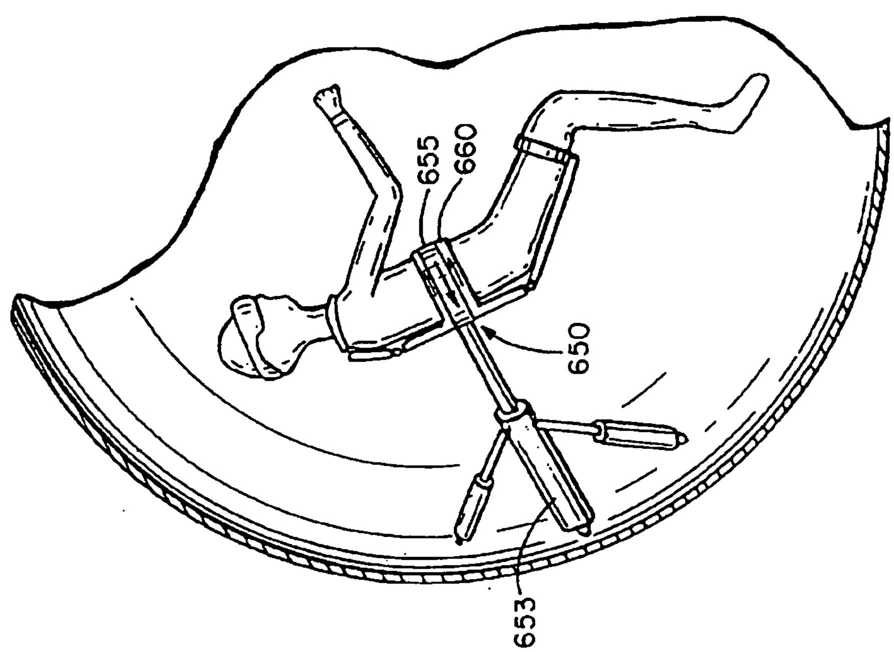

FIG. 19A

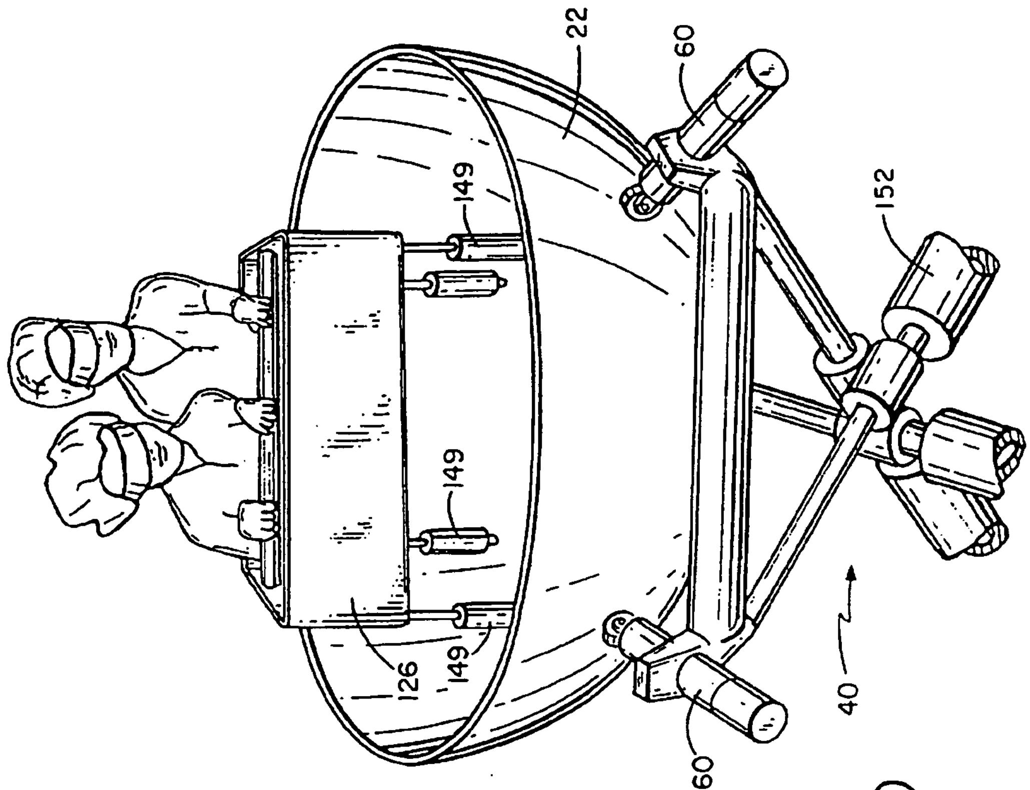

FIG. 20

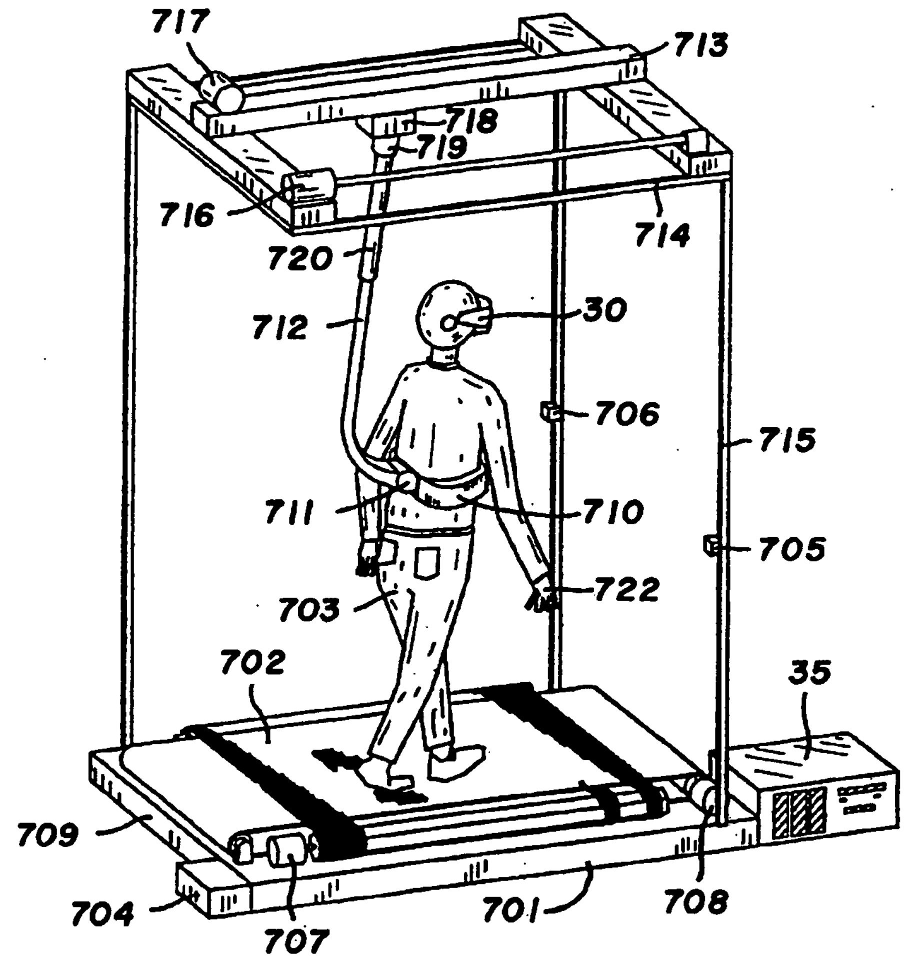
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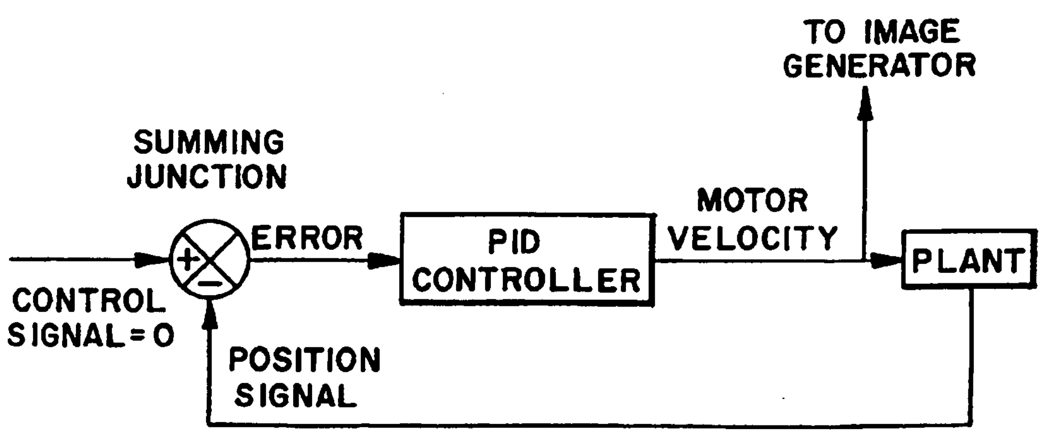
FIG.21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MOTOR VELOCITY
ERROR
PID CONTROLLER
PLANT
CONTROL SIGNAL=0
POSITION SIGNAL

FIG 22

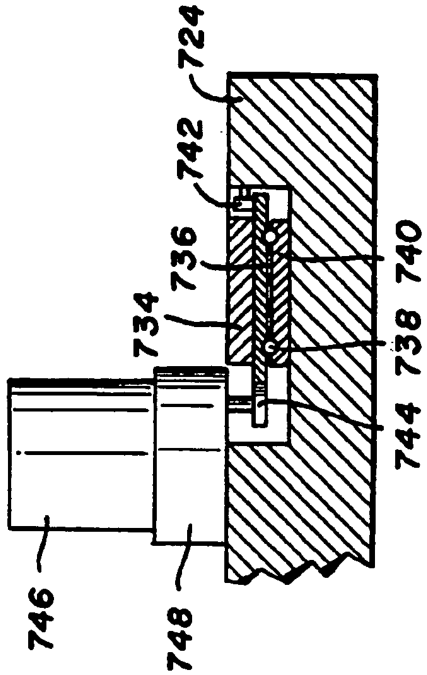


FIG. 23a

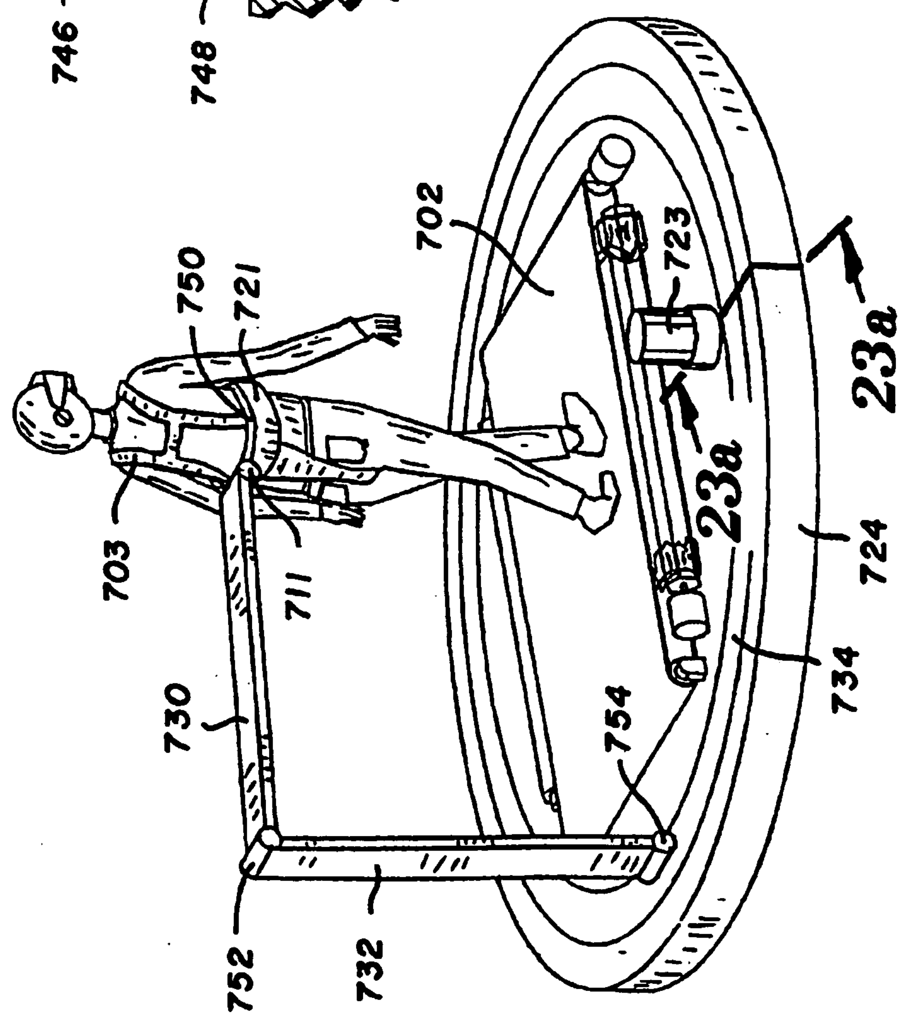


FIG. 23

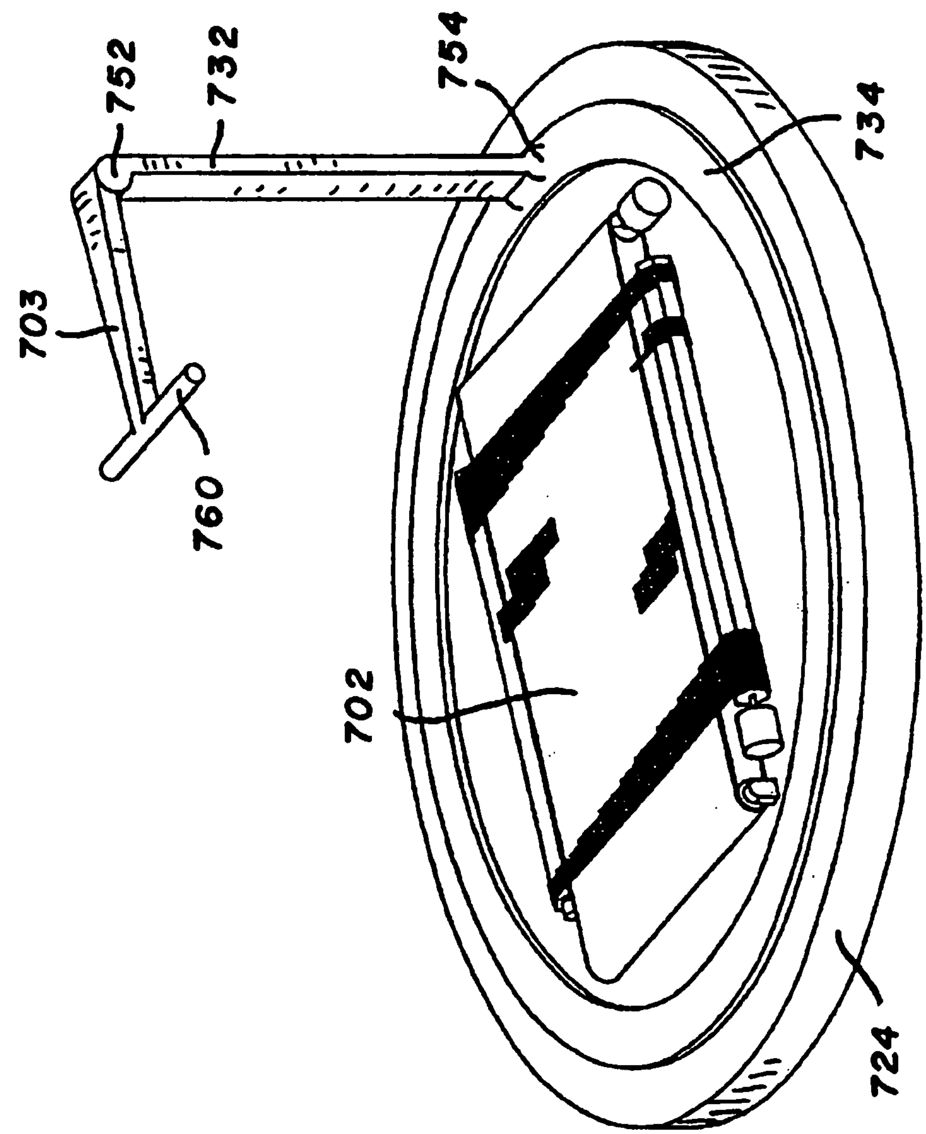


FIG. 24

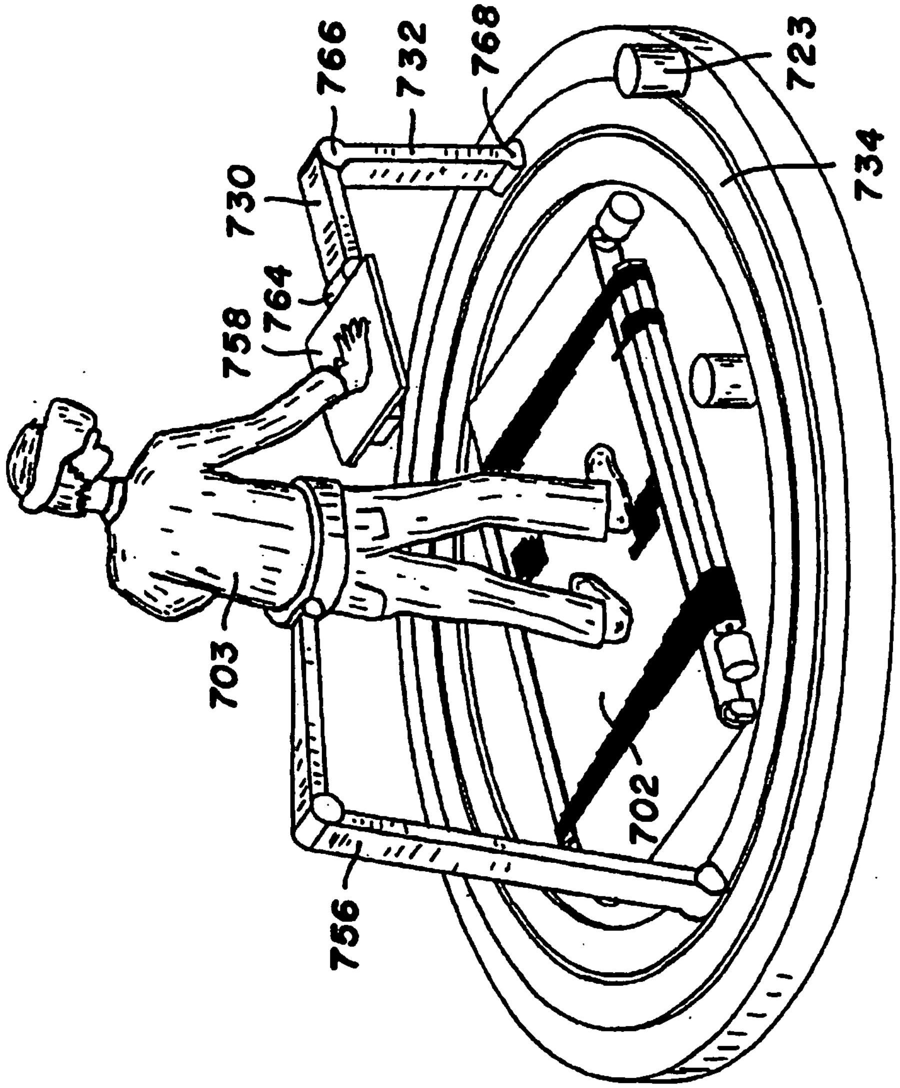


FIG.25

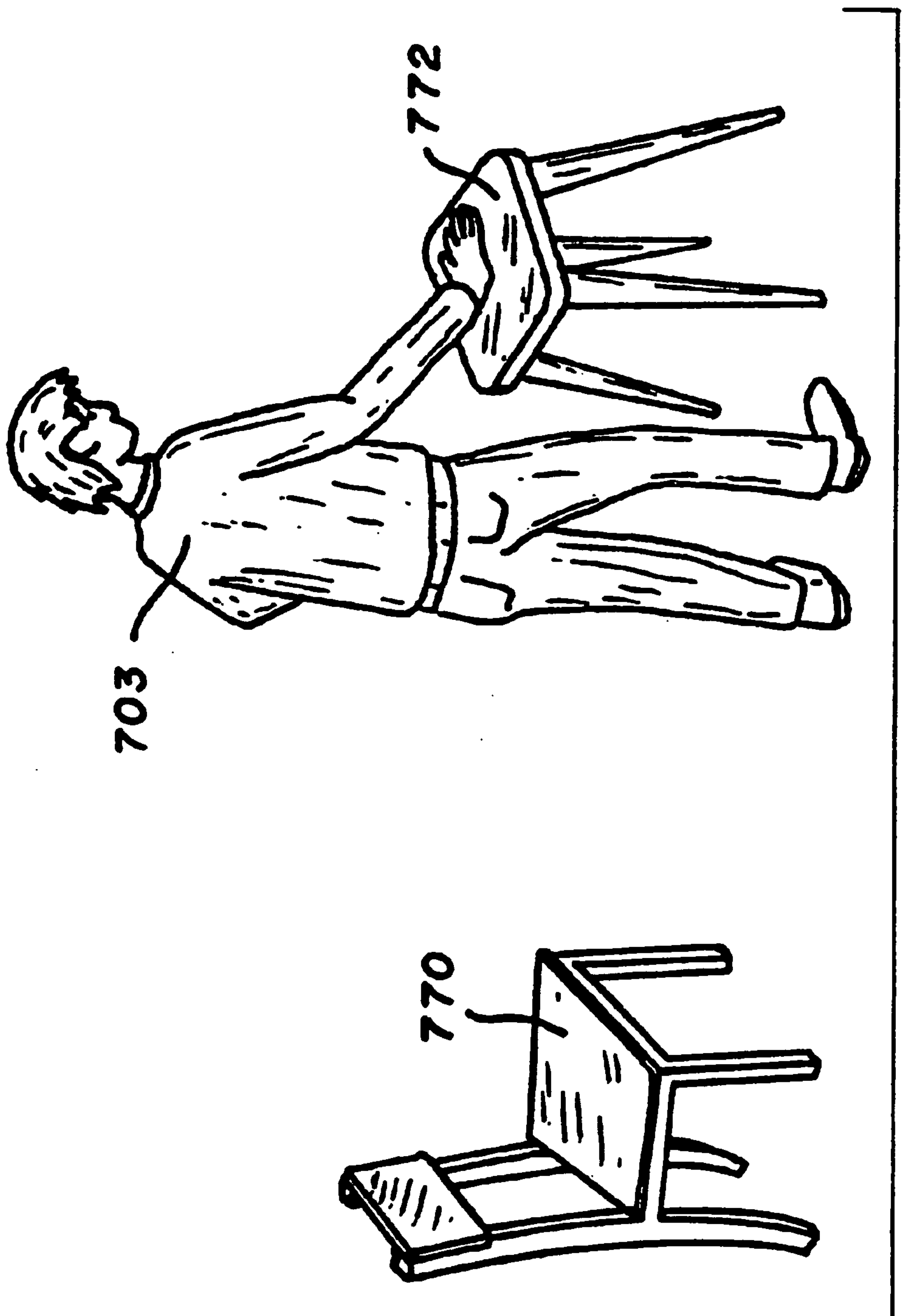
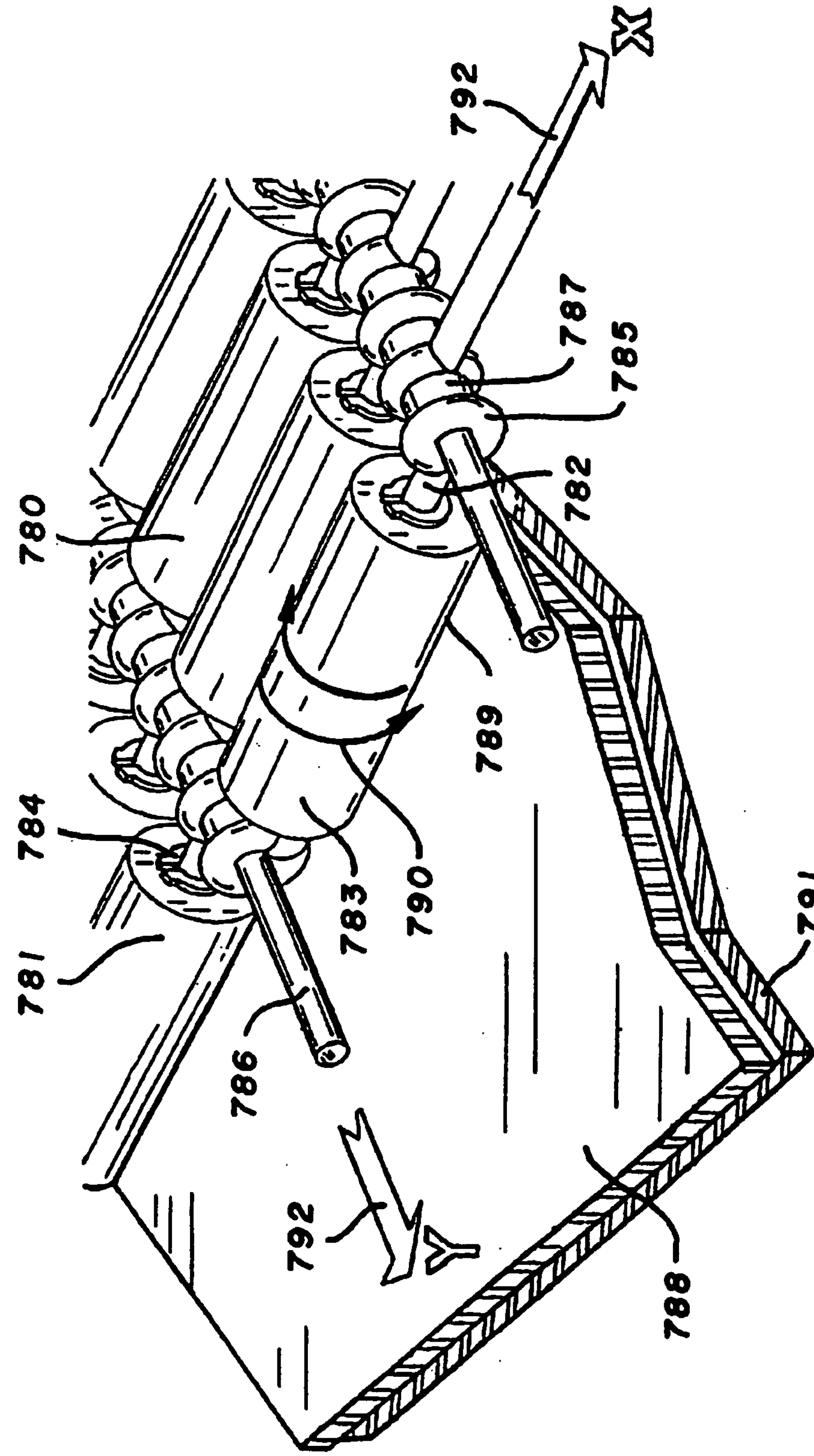


FIG. 26



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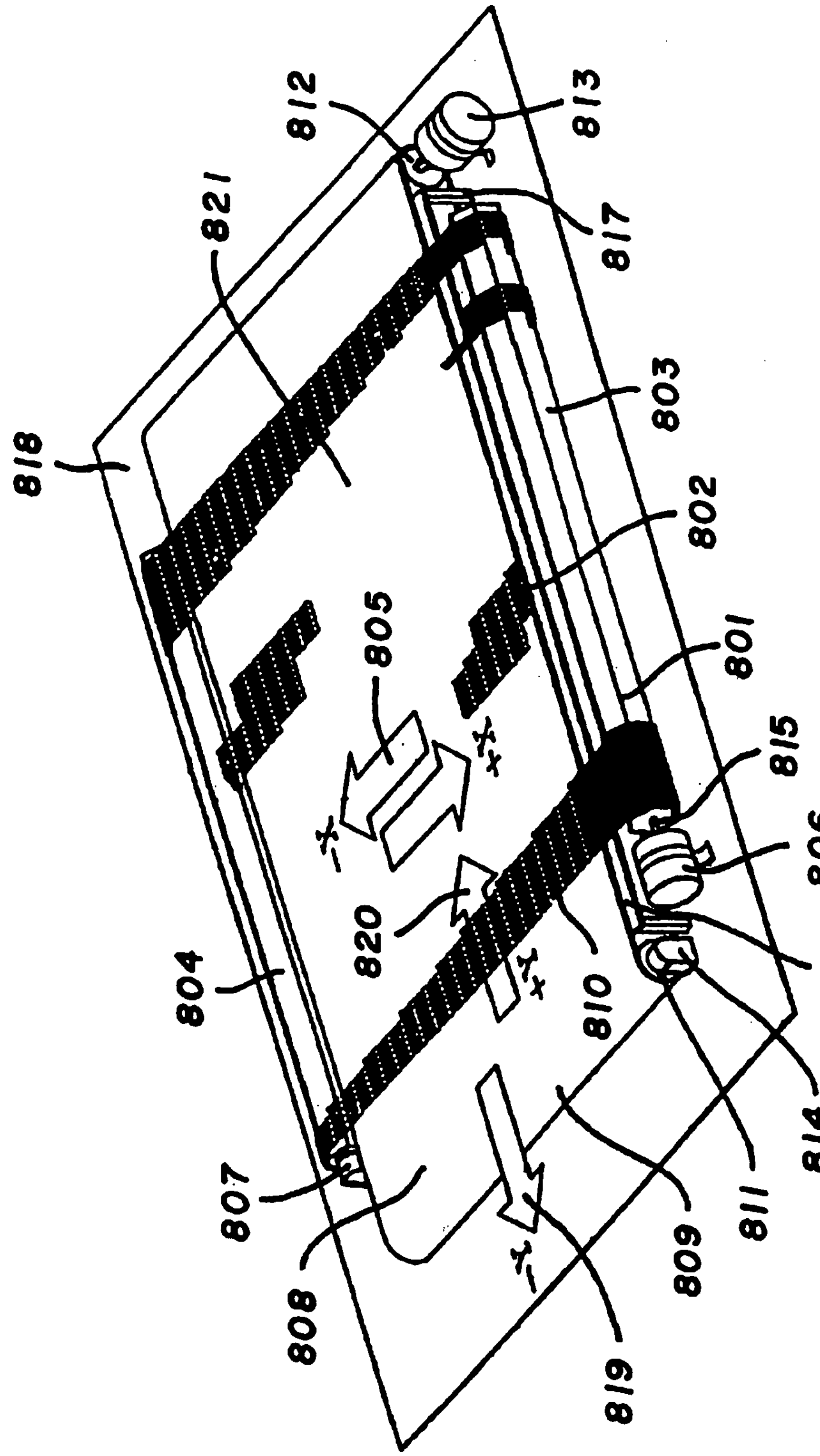
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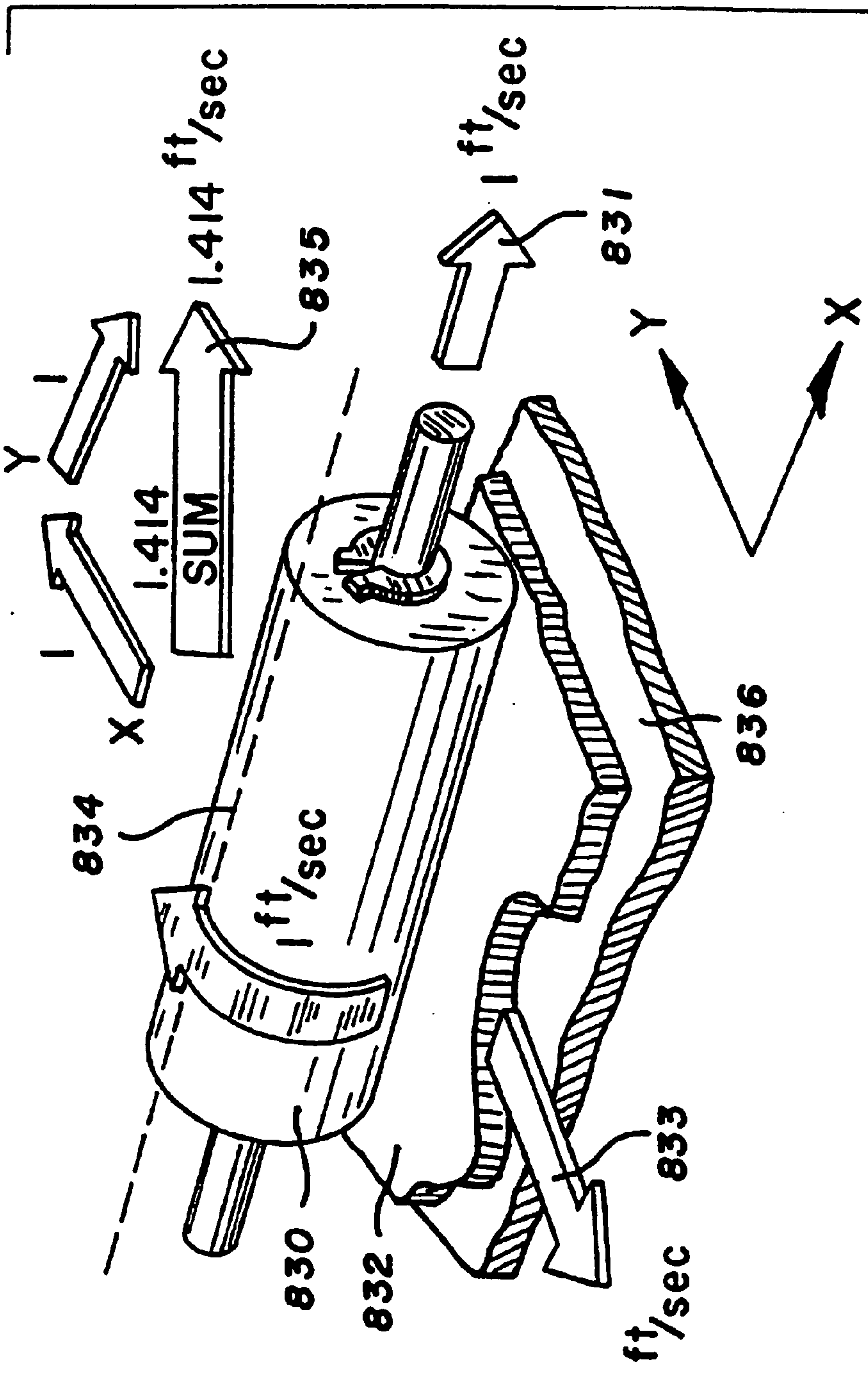
FIG.28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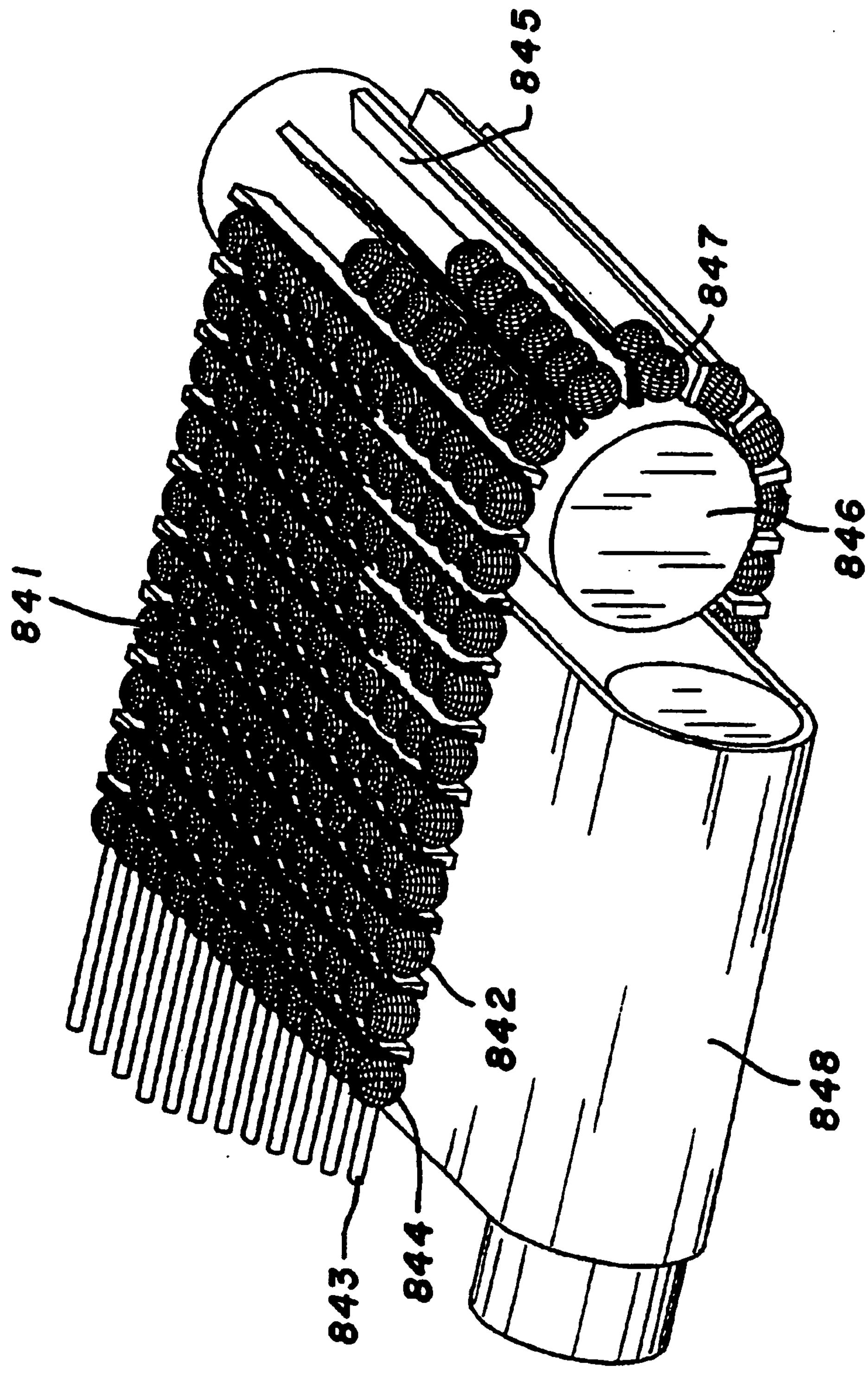
1 ft/sec

FIG. 29



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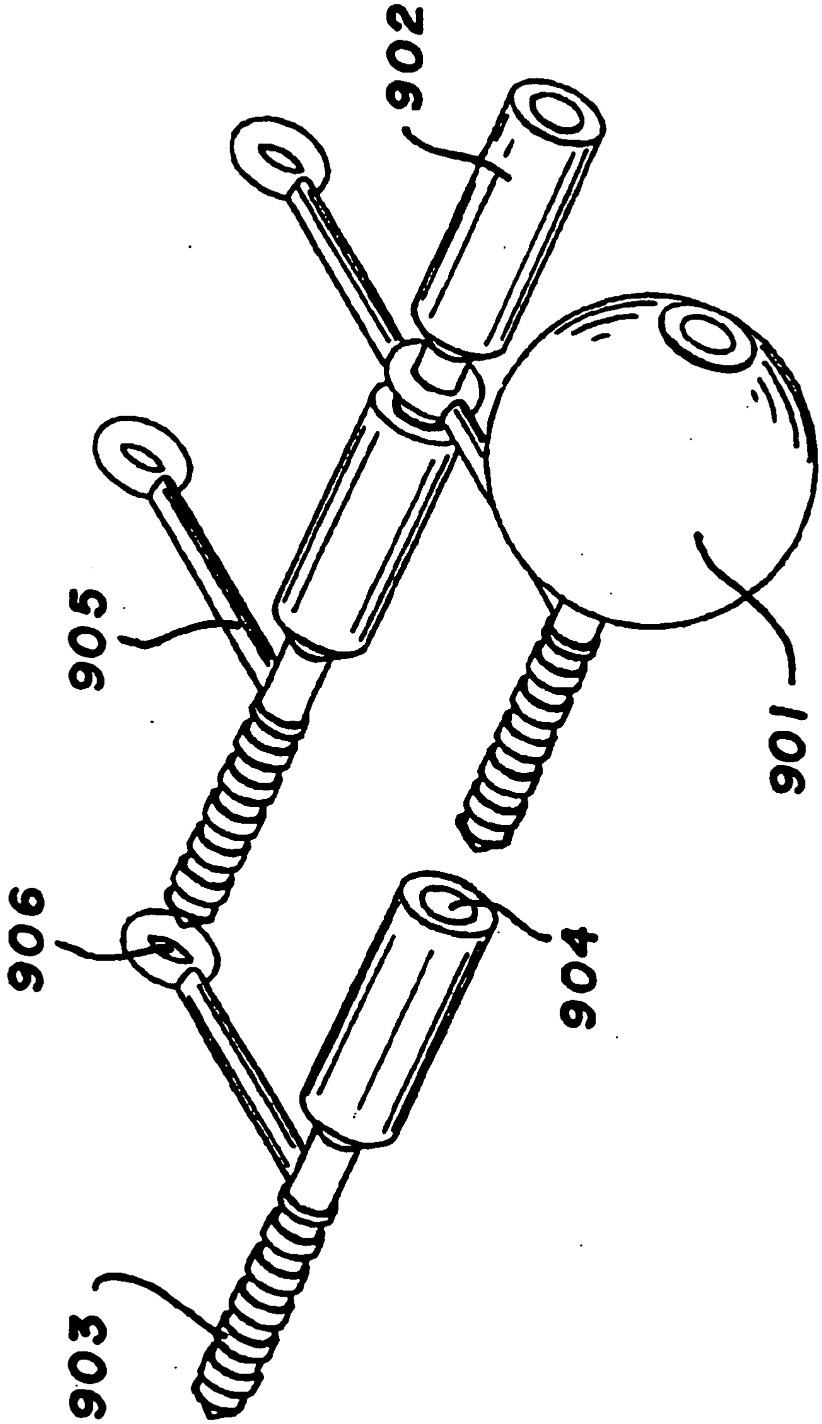

FIG. 31

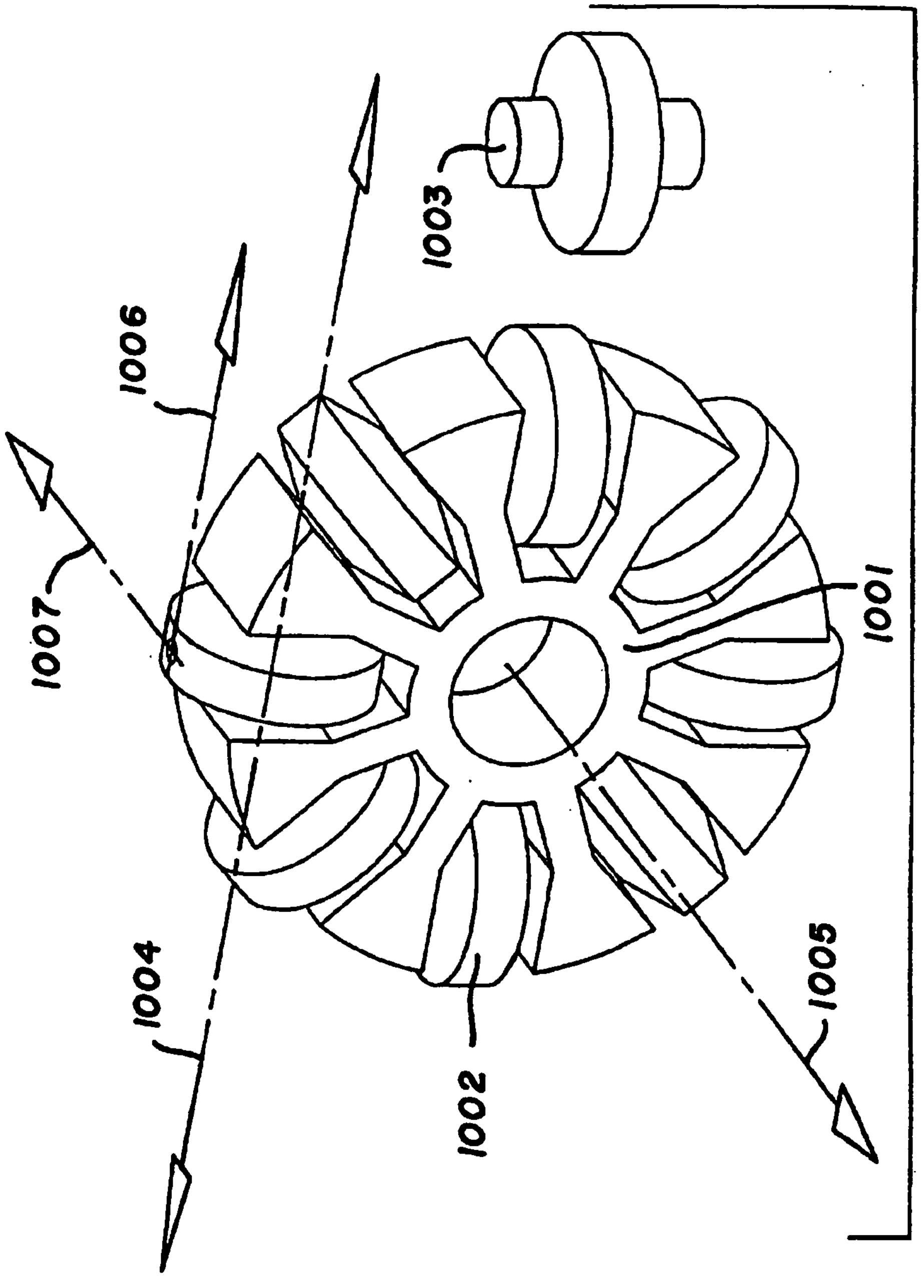

FIG.32

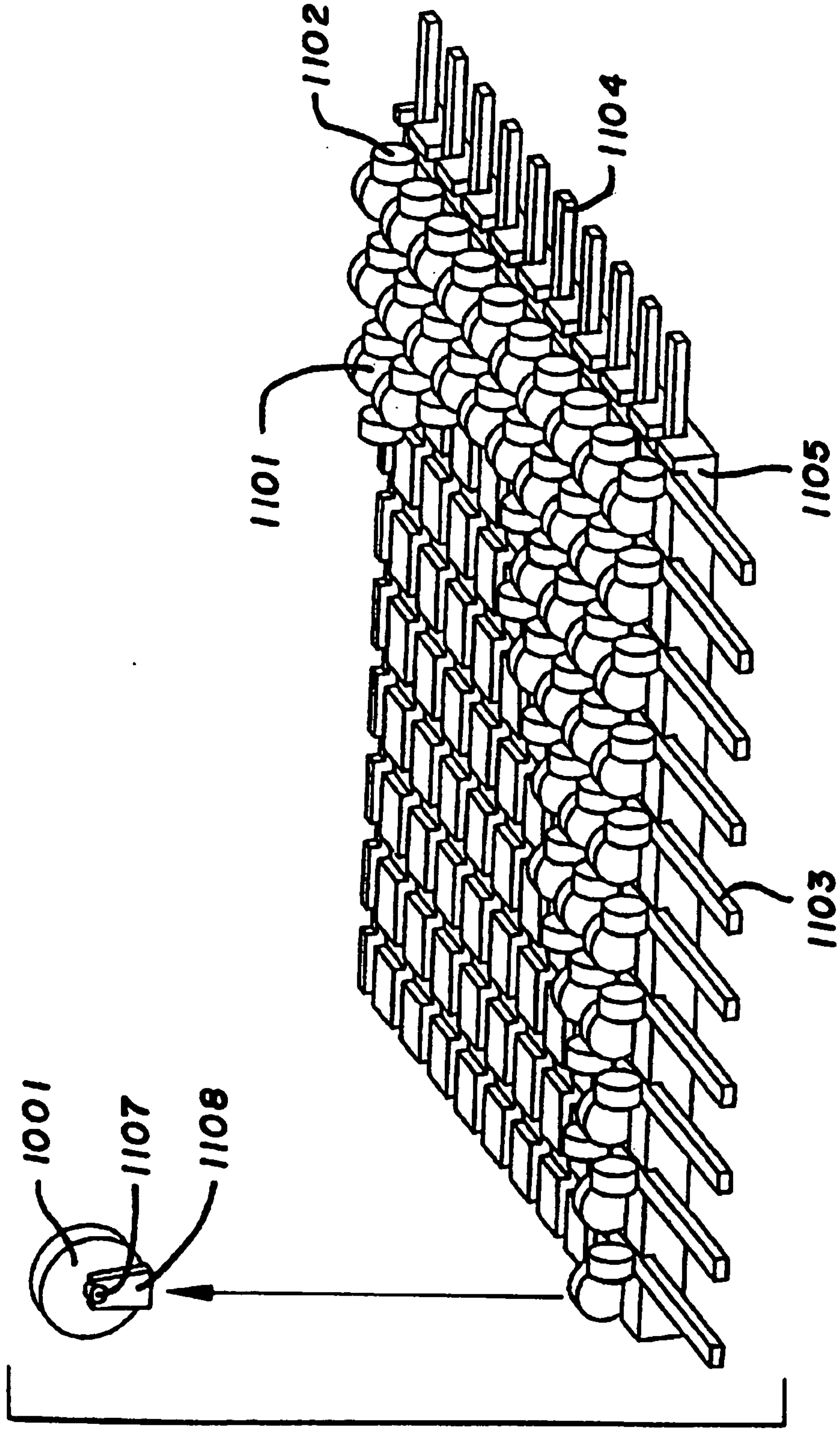

FIG. 33

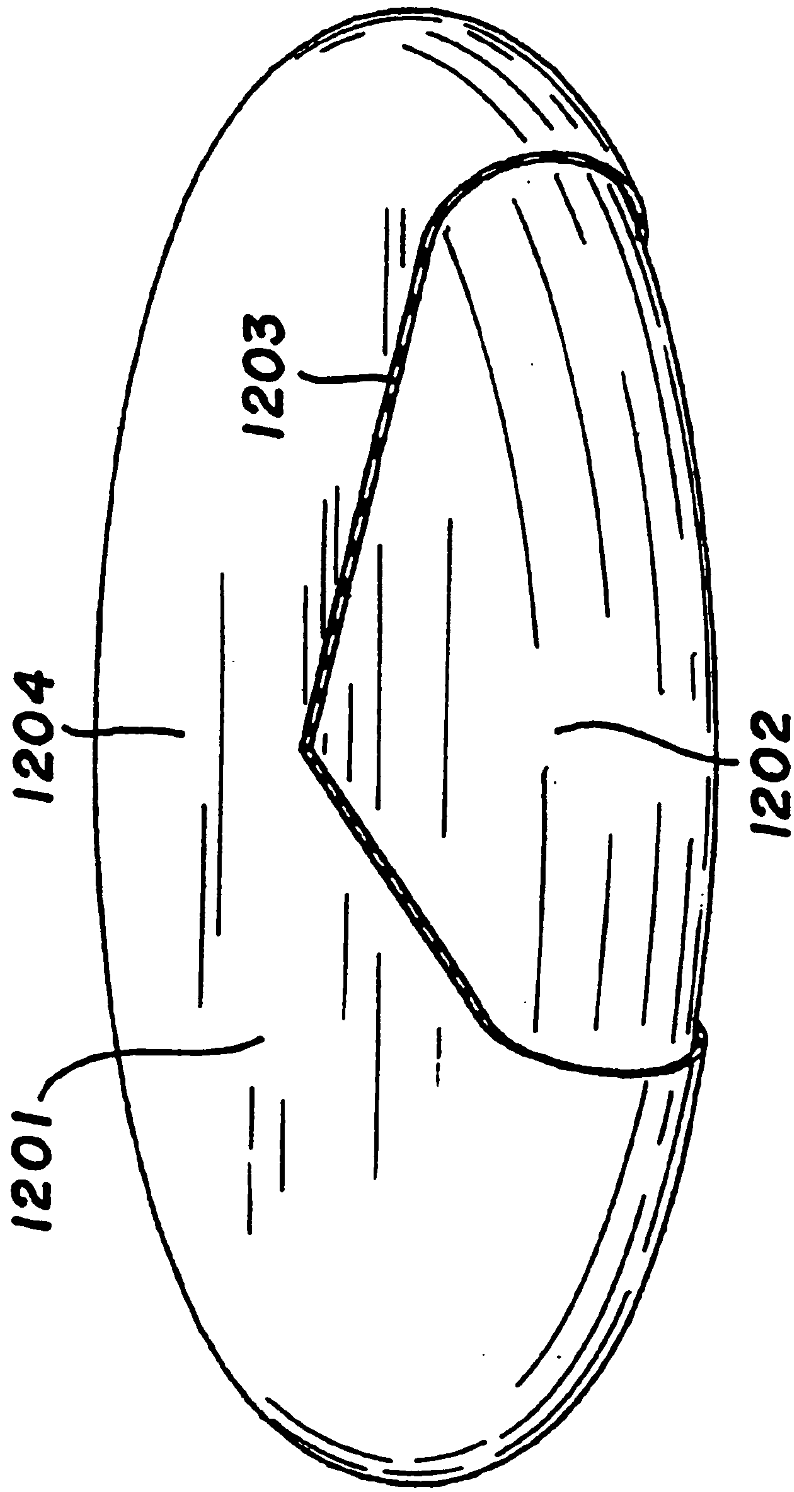

FIG. 34

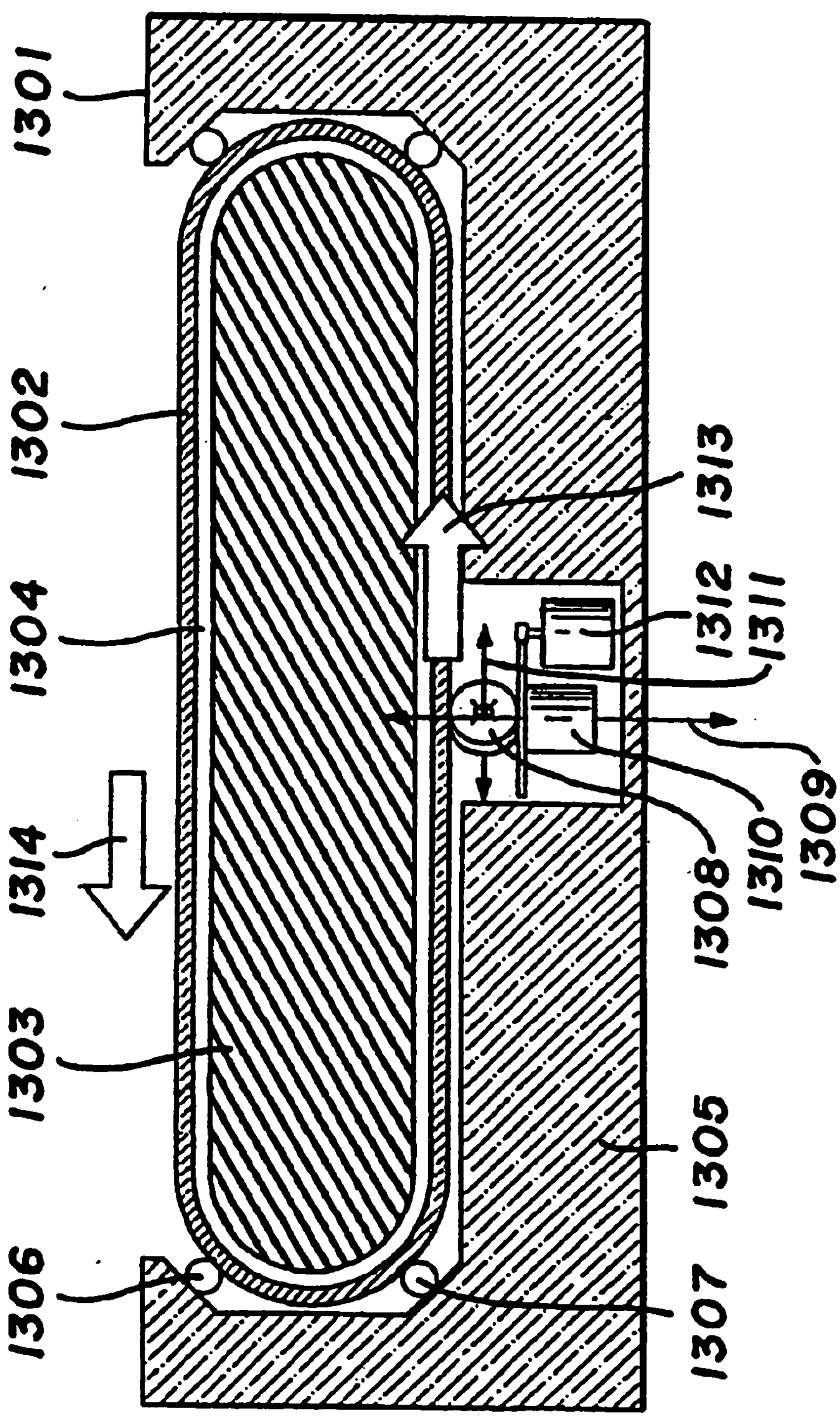
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FIG. 35

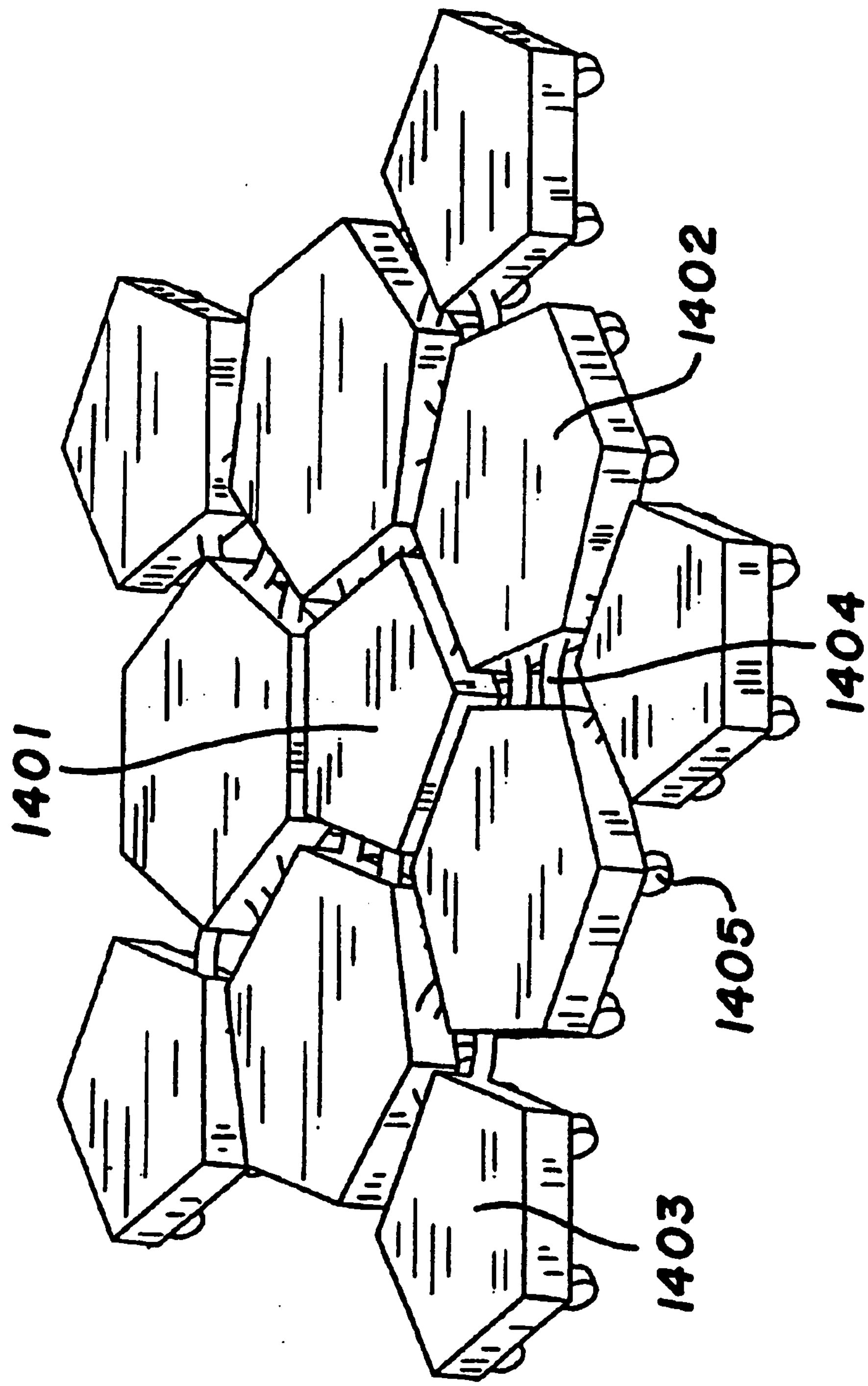


FIG. 36

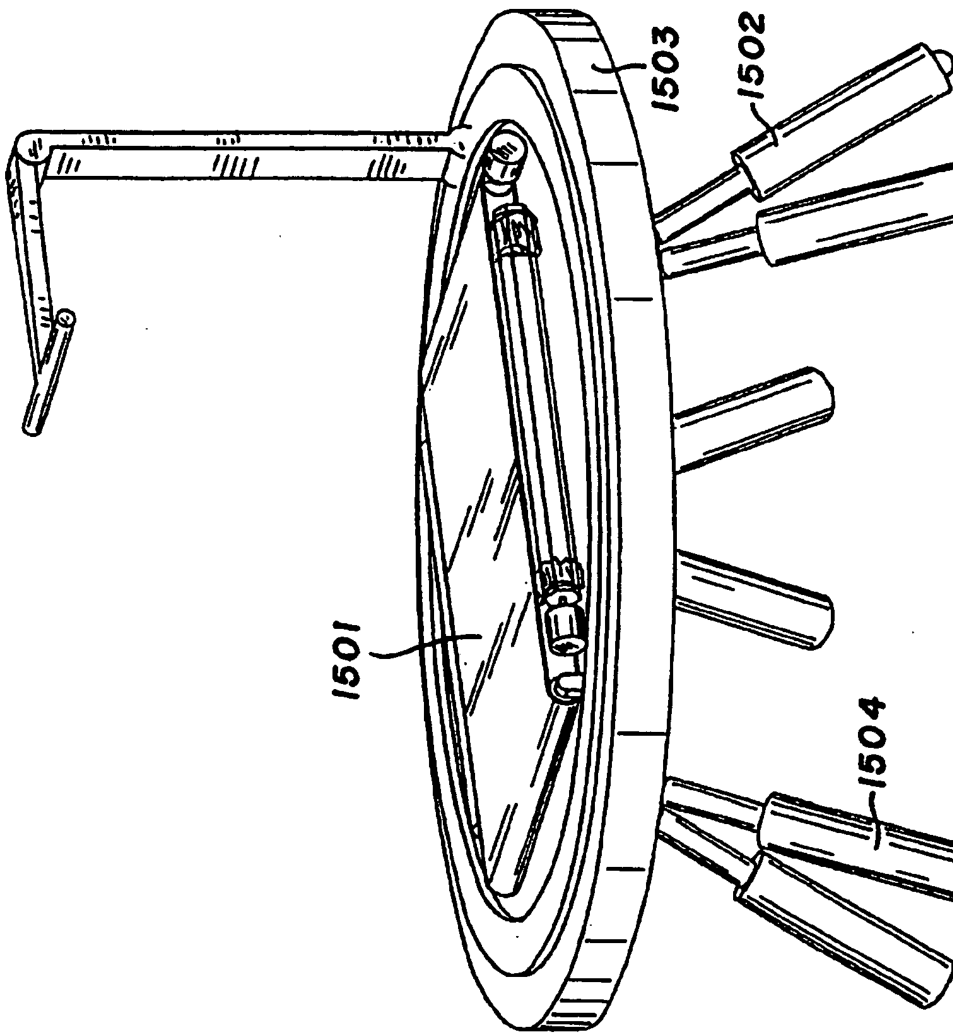


FIG. 37

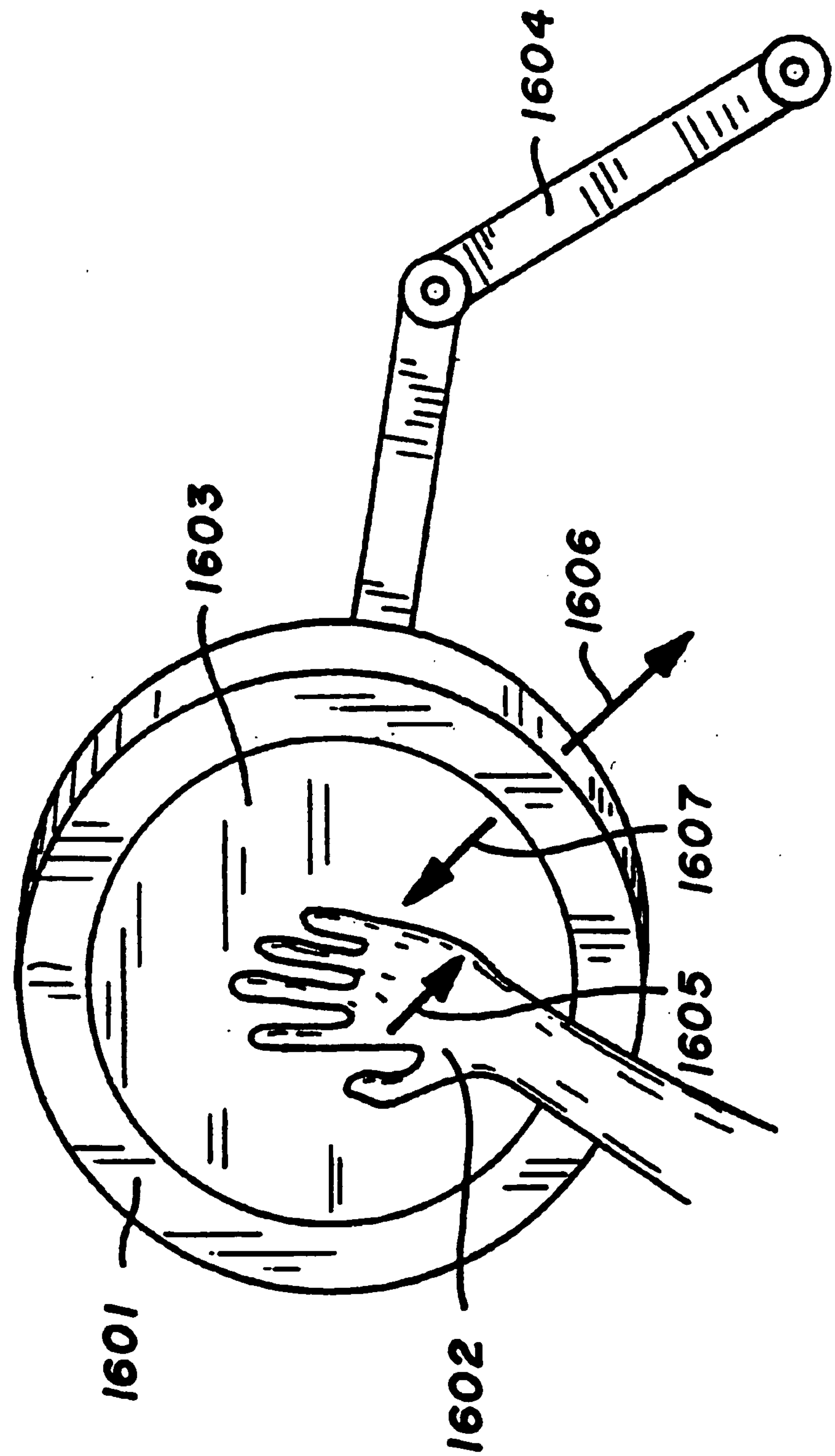


FIG. 38

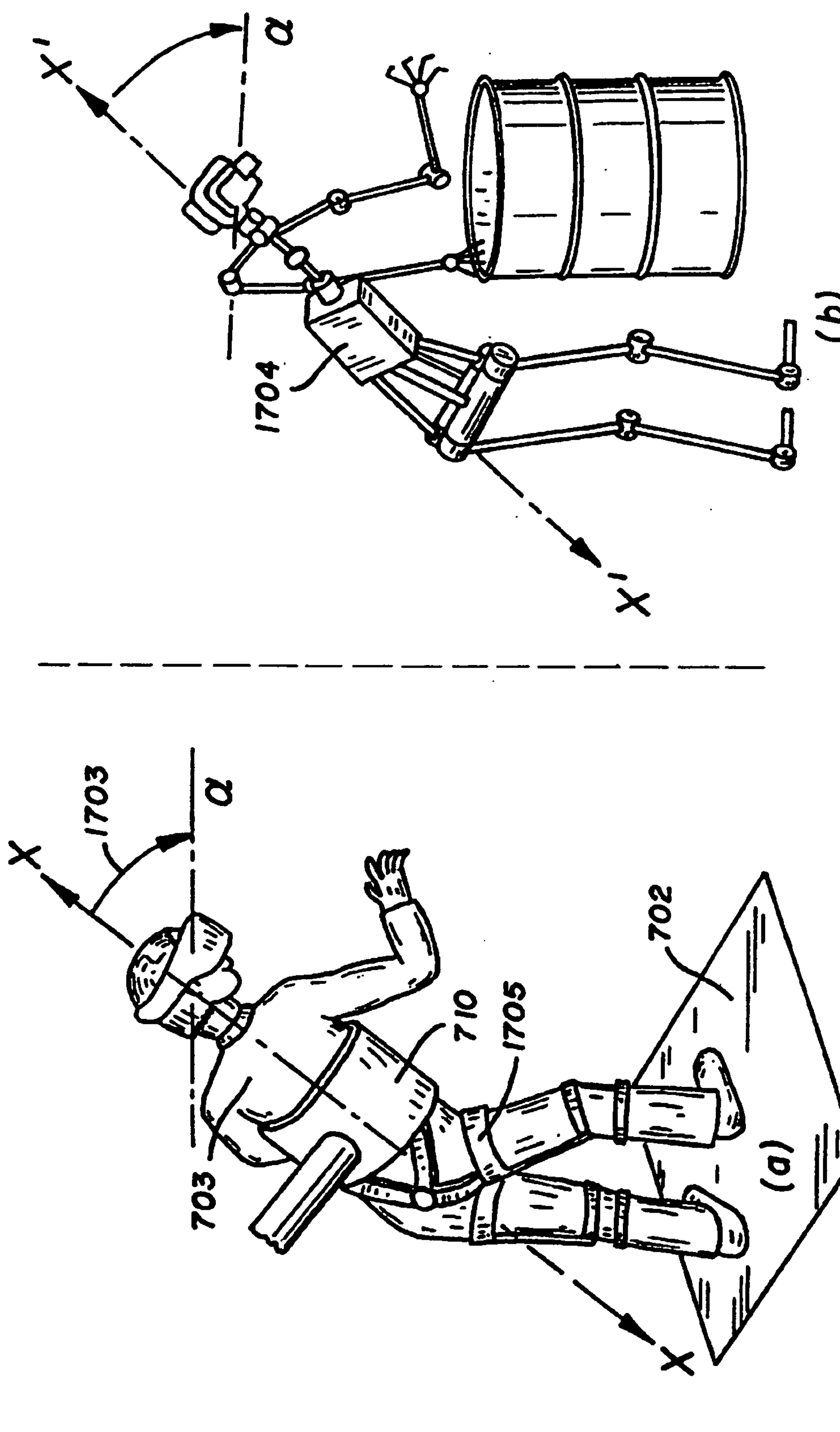


FIG. 39

VIRTUAL REALITY SYSTEM WITH ENHANCED SENSORY APPARATUS

RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 08/401,550 (filed Mar. 10, 1995), now U.S. Pat. No. 5,562,572, and of U.S. patent application Ser. No. 08/145,413 (filed Oct. 29, 1993), now U.S. Pat. No. 5,490,784.

FIELD OF THE INVENTION

The present invention generally relates to training and entertainment devices and provides a device particularly useful in interactive simulation environments such as are encountered in flight simulators, computer-based video games, and "virtual reality" systems.

BACKGROUND OF THE INVENTION

In virtual reality ("VR"), the sensation of motion is coordinated with the senses of sight, sound, and even touch. The "environment" that a person experiences is manufactured and contained in the silicon of computer processors and memory. Flight simulators used for training professional pilots and astronauts are a type of virtual reality system commonly in use today. As technology advances, the applications for "virtual reality" have grown well beyond such expensive, specialized equipment and are anticipated as being increasingly common as home entertainment or learning devices.

Although the hardware and software for generating the audio and visual components of virtual reality systems has been decreasing in cost, motion systems for use with such components to complete a virtual reality system have consistently been prohibitively expensive. Furthermore, the motion systems are either too complex, limited in their freedom of motion, or lack adequate responsiveness.

Various devices have been proposed for generating motion. U.S. Pat. No. 4,489,932, for example, describes a sphere resting on three passive casters, with motion of the sphere being actuated either by the user shifting his weight inside the sphere or by a multi-directional drive wheel. Another device for generating motion is found in U.S. Pat. No. 4,545,574, which discloses a sphere supported by an air stream moving within a large tube where the sphere is rotatable by louvers directing the force of the air around the sphere. Although both U.S. Pat. Nos. 4,489,932 and 4,454,574 describe a sphere rotatable about the three orthogonal axes at the center of the sphere, these devices cannot move the center of the sphere with respect to the external environment, i.e. they are not capable of linear motion. Moreover, these devices described in these patents also lack an interactive system coordinating motion, sight, and sound.

Other patents have proposed simulated motion devices which coordinate motion with audio and visual input. U.S. Pat. No. 3,135,057, for example, shows a capsule disposed within heavy inertial rings offset at 90° from one another. U.S. Pat. No. 4,856,771 shows a system that coordinates motion, video, and sound by using a cockpit situated inside two rings that are offset by 90° where the rings rest on a rotatable base. U.S. Pat. No. 5,060,932 describes a large gyroscope-like device where various means of visual and aural stimulations are provided. Although U.S. Pat. Nos. 3,135,057, 4,856,771, and 5,060,932 describe motion devices that combine motion with audio and visual input, they all are limited in their applicability to virtual reality systems because of their slow response or large expense.

U.S. Pat. No. 4,908,558 describes a spherical motion simulator mounted on a stationary frame for angular and translational movement along pitch, roll and yaw axes. Magnetic bearing supported by the stationary frame provide three degrees of freedom. Drive means mounted on the stationary frame and connected to the test unit generate three degrees of freedom of movement.

U.S. Pat. No. 5,071,352 describes a motion platform with limited translational and rotational motion. An arrangement of three linear actuators is combined with an A-frame type restraining mechanism to allow rotation about the pitch and roll axes and along a vertical axis. A multiple-user capsule sits on a rigid frame and users view images and experience sound in coordination with motion.

Current devices for simulating motion are cumbersome and expensive. As a result, the devices have slow response times. Moreover, these devices are limited in their ability to provide linear and rotational motion about three orthogonal axes.

A major limitation in state-of-the art VR is the inability to permit simple walking and running. Navigation is typically experienced as a disembodied center of consciousness which is directed by pointing, other gesture or by manipulation of a joystick, trackball, mouse, or similar device. The actual physical sensation of walking is limited to one of two forms: a) The user is restricted to a confined and immobile surface where tracking and signal generation are well-controlled, and b) the user is confined to device such as a linear treadmill or wheelchair which transduces the user's linear motion to virtual space navigation. The conventional linear treadmill has a movable track which can be upwardly inclined. The track is only movable in one direction which restricts motion of the user to the direction of movement of the track. A monitor, such as a motivational electric display, associated with the track, records the time, speed, and distance accomplished by the user.

Use of a linear treadmill, consisting of one continuous moving track, in conjunction with a monitor permits a user to walk in a straight line. The user cannot step in arbitrary directions as he or she would be able to in real life. This limitation in directionality detracts from the immersive nature of the experience, and requires that the experience take on more of a vehicular nature rather than freely walking and navigating body.

SUMMARY OF THE INVENTION

The present invention provides a mechanical system for creating motion with six full degrees of freedom; three rotational degrees of freedom and three linear-translational degrees of freedom. In its broader aspect, the present invention enables a user to physically experience full freedom of motion within a limited space.

In a preferred embodiment, the present invention provides a device in which the user will experience full freedom of motion in coordination with the user's senses of sight, hearing, and touch. A user utilizing the motion simulating device of the present invention will be able to interact with an electronic environment using many of the same senses used in the natural world. The claimed invention enables interaction with an electrically generated environment by employment of the user's natural center of balance center and sense of direction.

In its basic form, the motion simulating device consists of a generally spherical capsule that is supportively abutted by a number of rollers. At least one of the rollers is a multi-directional active roller that frictionally engages the capsule

causing the capsule to rotate in any direction. A preferred embodiment uses three active rollers to impart rotational motion to the capsule. All rotational modes may be provided by rotating the sphere upon the rollers.

The linear, or translational, motion is imparted to the capsule by attaching the rollers to a movable frame. The translational modes are achieved by using actuator legs capable of moving the frame along one axis or, more preferably, with respect to three orthogonal axes.

Optimally, an interactive control means that coordinates sight, sound, and touch may be operatively connected to the capsule, active rollers, and frame. Through the interactive control means, a user may control and respond to a variety of environments and experience the corresponding motion associated with the user's control.

One objective of this invention is to enable the user to physically experience full freedom of motion in a responsive and less expensive device. Another objective of the invention is to permit a user to move in coordination with electronic simulation physical reality.

In accordance with another embodiment of the invention, active interactive solids and passive interactive solids are incorporated into a virtual reality system to impart the sensation of touch to the user. Interactive solids generally may be used to impart physical confirmation of what the user is touching in the virtual electronic environment. Active interactive solids are self-actuating objects operatively connected to the interactive control means. Active interactive solids may move in coordination with the electronic simulation of physical reality and physical input from the user. Passive interactive solids are not self-activating, and as such, provide physical confirmation of fixed objects generated in the virtual environment.

An active interactive solid may include an interactive support apparatus which is disposed within the capsule to impart the sensation of touch to the user. The interactive support apparatus includes a translatable support arm connected to a pneumatic support suit. A user can experience the sensation of support such as floating in water or other physical activity by imparting resistive forces to the pneumatic support suit.

The instant invention imparts full rotational freedom while minimizing the number of moving parts. Such freedom may be experienced as a "barrel" roll as they fly in a virtually-created fighter jet, or the tumbling of a virtual car involved in an end-over-end drivers' training accident.

The present invention efficiently utilizes the relatively low moment of inertia inherent in a rigid and light spherical structure. A maximum of rotational acceleration and deceleration is realized around all axes by utilizing a generally spherical capsule, minimizing the number and complexity of moving parts, and generally centering the interior mass.

In another embodiment, the invention employs an interactive solid which is similar to a linear treadmill in that the user is able to walk or run in an upright manner and employ proprioceptive sensing along with balance to imbue a sense of reality to the simulated environment. Alternatively, the user may assume any manner of postures with respect to the planar active surface. Other postures include kneeling, crawling on hands and knees, belly crawling, sitting and lying prone.

This embodiment of the invention employs an omni-directional treadmill apparatus that allows a user, such as a person, to walk or run in any arbitrary direction. The apparatus has a frame for supporting the apparatus on a fixed surface. A track assembly mounted on the frame provides a

user support that moves in a direction determined by directional orientation of the user on the track assembly. The track assembly has a user support movable in first direction by a first drive motor. The user support means includes user support members rotatable about axes generally normal to the direction of movement of the support. A second drive, such as a power driven endless belt, engages the user support members to rotate the user support members whereby the combined movement of the user support members and user supports results in omni-directional user movement. Controls responsive to the directional orientation of the user on the user support selectively control the operation of the first and second drives which in turn controls the directional user movement to conform with the orientation of the user on the user support.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevational view of a motion simulating device in accordance with the invention;

FIG. **2** is an elevational view of a motion simulating device in accordance with another embodiment of the invention;

FIG. **3** is an elevational view of a third embodiment of the present motion simulating device;

FIG. **4** is a cut-away view of an active roller for use in the invention;

FIG. **5** is a top view of an alternative active roller in the invention;

FIG. **6** is a cross-sectional view of another active drive roller in the invention;

FIG. **7** is a perspective view of an interactive support apparatus in accordance with the invention wherein the user is in a reclining position;

FIG. **8** is a perspective view of an alternative interactive support apparatus, where the user is in a suspended position;

FIG. **9** is a perspective view of yet another interactive support apparatus which includes translational means;

FIG. **10** is a cut-away view of a motion simulating device with interactive solids of the invention;

FIG. **11** is a cut-away view of a motion simulating device with interactive solids in accordance with another embodiment;

FIG. **12** is an elevational view of an interactive solid for stepping;

FIG. **13** is an elevational view of an interactive support apparatus coupled to an interactive pneumatic support suit;

FIG. **14** is a cut-away view of the interactive pneumatic support suit of FIG. **13**;

FIG. **15** is a cross-sectional view of a section of the interactive pneumatic support suit of FIG. **13**;

FIG. **16** is a partially broken-away schematic view of a motion simulating device of the invention including passive interactive solids;

FIG. **17** is an elevational view of an interactive solid in accordance with another embodiment of the invention;

FIG. **18** is an elevational view of an interactive solid in accordance with another embodiment of the invention with a positioning track;

FIG. **19** is an elevational view of an interactive support apparatus in accordance with another embodiment of the invention;

FIG. **20** is an elevational view of a motion simulating device of the invention with high-frequency internal actuators;

FIG. 21 is a perspective view of an omni-directional treadmill in accordance with a further embodiment of the invention;

FIG. 22 is a block diagram of a motor control for use with the treadmill of FIG. 21;

FIG. 23 is a perspective view of an alternative embodiment of a treadmill of the invention;

FIG. 23a is an enlarged sectional view taken along line 23a—23a of FIG. 23;

FIG. 24 is a perspective view of another embodiment of a treadmill of the invention;

FIG. 25 is a perspective view of yet another embodiment of a treadmill of the invention;

FIG. 26 is a diagrammatic view showing a user in real space;

FIG. 27 is a perspective view of a section of a track assembly employed in the embodiments of a treadmill such as those in FIGS. 21 to 25;

FIG. 28 is another perspective view of a track assembly employed in the embodiments of a treadmill such as those in FIGS. 21 to 25;

FIG. 29 is a diagrammatic perspective view, similar to FIG. 27, showing the movement of rotatable sleeves and a sleeve drive belt;

FIG. 30 is a perspective view of an alternate embodiment of a track assembly useable with embodiments of treadmills similar to FIGS. 21 to 25;

FIG. 31 is an exploded perspective view of a section of another embodiment of a track assembly useable with embodiments of treadmills similar to FIGS. 21 to 25;

FIG. 32 is a perspective view of an embodiment of an omni-directional wheel and idler rollers;

FIG. 33 is a perspective view of an embodiment of a track assembly useable with a treadmill similar to FIGS. 21 to 25;

FIG. 34 is a perspective view, partly sectioned, of a spheroid treadmill segment;

FIG. 35 is a sectional view of a segment of FIG. 34 incorporated in a track assembly;

FIG. 36 is a perspective view of an alternate embodiment of an active surface of a track assembly;

FIG. 37 is a perspective view of a treadmill similar to that of FIG. 24 but including a hexapod motion platform;

FIG. 38 is a perspective view of an active surface haptic display; and

FIGS. 39a and 39b are diagrammatic views showing how the user at one site controls a remote device at a distant site.

DETAILED DESCRIPTION OF THE INVENTION

A motion-simulating device (10) embodying the invention is illustrated in FIGS. 1–3. The device (10) comprises a generally spherical capsule (20) that rests on at least three rollers, with one or more active rollers (60) and, optionally, one or more passive rollers (99). These rollers are attached to a translatable frame (40).

In a preferred embodiment, a capsule is supportively abutted by three rollers of which two of the rollers are multi-directional active rollers. The rollers are then attached to a triangular platform which is linearly translatable along three orthogonal axes by six actuator legs. Each apex of the triangular platform is rotationally connected to two actuator legs and each of the actuator legs is rotationally connected on the other end to the ground. The visual and audio input, as well as the responsive output from the user, are then processed by computers which control the active rollers and actuator legs.

FIG. 1 shows a capsule (20) having an upper hemisphere (21) and a lower hemisphere (22). The upper hemisphere (21) and the lower hemisphere (22) may be hingedly connected at an internal hinge (24) and open along an equatorial contact line (25). The capsule (20) is fitted with a chair (26) and a set of full restraint harnesses (28). A user may receive visual input from a head-mounted visual display (30) and audio input from earphones (31) or speakers within the sphere (not shown). In an alternative embodiment, the visual input may be displayed upon the inner walls of the capsule (20).

When operating the virtual reality system, the user may control the motion of the frame (40) and the capsule (20) by a suitable controller. In the embodiment shown in the drawings, the controller may comprise two control sticks (32) with each control stick being capable of controlling three degrees of freedom, as detailed below.

The translatable frame (40) shown in FIG. 1 has three beams (42) which are rigidly connected to one another by connecting joints (44) at beam receptacles (45) to form a triangular platform (41). Each connecting joint (44) includes a mounting plate (46) for supporting either an active roller (60) or a passive roller (99). Each connecting joint (44) is supported by two actuator legs (48). The actuator legs (48) may each comprise a movable rod (53), a support housing (52), an actuating motor (50), and a gear reduction means (51). The movable rod (53) is driven by the actuating motor (50) so that the movable rod travels along the longitudinal axis of the support housing (52). The actuator legs (48) are attached to the connecting joints (44) and to the ground by rotatable connectors (55). By selectively and differentially moving the actuator legs (48), the triangular frame (41) can be translated along any of the three orthogonal axes. Such a construction is known to those skilled in the art as a Stuart platform. It is recognized that the movement of the triangular platform (41) may be effected by a variety of constructions of rigid members, flexible members, bearings, sliders, motors, and related motion system components.

The active rollers (60) and the passive rollers (99) are attached to the connecting joints (44) at the mounting plates (46). In a preferred embodiment, the capsule (20) is driven by two active rollers (60) about three orthogonal axes located at the center of the capsule (20), and a single passive roller (99) rests substantially upon a thrust bearing (98).

Each active roller (60) includes a drive wheel (70) that is attached to a rotating yoke (80). The drive wheel (70) is driven by a drive wheel motor (72) and a reduction means (73). The drive wheel (70) is rotatable about a drive axis "A—A" that is generally parallel to a tangent to the surface of the capsule (20). The drive wheel (70) frictionally engages the capsule (20) and causes the capsule (20) to rotate in a direction perpendicular to both the drive axis "A—A" and axis "B—B." The drive wheel (70) is rotatable about axis "B—B" by rotating the yoke (80). The yoke (80) is rotatably driven by the yoke motor (81) and a reduction means (82). In a preferred embodiment, the capsule (20) may be coated with a friction enhancing substance such as silicon carbide particles encapsulated by a spreadable liquid binder, or the surface may be roughened by a light sand blasting to enable faster rotational acceleration.

The active rollers (60) and the actuator legs (48) are controlled by an interactive virtual reality control system. The rotational position of the capsule (20) is measured, e.g.,

by a gyroscope (33), and the measurement, e.g., output from the gyroscope, is routed through an internal computer (34), which may be located inside the capsule (20). Once position information is processed by the internal computer (34), the data is optimally sent through a transmitter (36) to a receiver (37). The receiver (37) then sends the position data to the main computer (35), which may be located outside of the capsule (20).

The main computer (35) is also connected to the actuator motor controllers (57) and the active roller controllers (62). The actuator motor controllers (57) control the actuator legs (48). The active roller controllers (62) are connected to the active rollers (60) by a cable (64). The main computer (35) may also receive position data from the actuator legs (48) to determine the translational location of the platform (41).

While using the interactive virtual reality control system, a head-mounted display adjusts the images it displays in response to the user's movements. Data entry in the sphere for visual images, sound, and touch, can use a high-speed digital laser transmission system having a wide-beam transmitter (38) and a plurality of capsule receivers (39). Such capsule receivers (39) are evenly spaced on the outside of the capsule (20). The data entering the capsule (20) is processed by the internal computer (34) and then routed to the head-mounted visual display (30) and the earphones (31). An internal battery (29), which is rechargeable during periods of non-use and readily replaceable, powers the electrical system inside the capsule (20). A line voltage supply (58) connected to a power supply (59) provides the power for the electrical components located outside of the capsule (20).

FIG. 2 shows an alternative embodiment of the invention employing a different actuator leg system. The capsule (20) is supported by the active rollers (60) whose drive means are attached to the triangular platform (41) through the connecting joints (44). Linear actuation is achieved by placing the triangular platform (41) on top of a tripod comprised of three actuator legs (148). Every connecting joint (44) is supported by a single actuator leg (148). The actuator legs (148) may have the same structure as the legs (48) detailed above. Preferably, though, the legs (148) comprise a ball screw (153) (shown through cutaway), a supporting housing (152), an actuating motor (150), and a gear reduction means (151). Rotatable ball joints (155) attach the actuator legs (148) to the triangular platform (41) and to the ground. The actuator legs (148) are positioned relative to each other at their centers by a sliding fastener plate (156) through linear-rotational bearings (157). The ball screw (153) is held within a smooth-walled upper support cylinder (154) so that the linear rotational bearings (157) have a smooth and rigid surface upon which to travel.

As the actuator legs (148) change their lengths, the sliding fastener plate (156) passively seeks a position that keeps the tripod of actuator legs (148) rigid and stable. The tripod arrangement of actuator legs (148) as depicted in FIG. 2 will impart a known rotation about the vertical axis for any linear motion transmitted. Such rotation about the vertical axis may be negated by an equivalent counter-rotation of the capsule (20) itself. It is recognized that the movement of the triangular platform (41) may be effected by a variety of constructions of rigid members, flexible members, bearings, sliders, motors, and related motion system components.

In FIG. 3, a motion simulating device (210) having four degrees of freedom is depicted. The motion simulating device (210) retains full rotational motion, but linear motion is limited to up and down. In the embodiment shown in FIGS. 1 and 2, communication between the internal and man computers (24 and 35, respectively) is accomplished through the transmitter (36) and receiver (37). FIG. 3 illustrates a less expensive, though somewhat more cumbersome, system using a fixed cable. In this version, rotation around either horizontal axis is limited by the cable ring (223), which can serve as a movable means of attachment for a dedicated data exchange and a power cable (227). The motion simulating device (210) has a single translational mode which is along its vertical axis. The active rollers (160) rotate the capsule (220).

In the embodiment of FIG. 3, a user with a head-mounted visual display (30) is visible through an access port (228) in the upper hemisphere (221). A single actuator (227), attached to the ground at one end and an apex-connecting joint (241) at the other end, provides the single translational motion along the vertical axis. The apex-connecting joint (241) is connected by rigid supports (243) to the connecting joints (244). Stability is enhanced by rigid attachment of the sliding members (249) to the connecting joints (244). The sliding members (249) are free to move vertically, but are constrained in all other directions by housings (252) that are attached rigidly to the ground.

FIGS. 4–6 show a variety of active roller embodiments. FIG. 4 depicts a plan view of an active roller (60) with a single drive wheel (70). The drive wheel (70) makes frictional contact with the surface of capsule (20). Rotation of the drive wheel (70) about the drive axis "A—A" rotates the capsule (20). Rotation of the drive wheel (70) about a perpendicular axis "B—B" changes the direction of the drive wheel (70). A yoke assembly (80) houses both the bearings (71) for the drive wheel (70), and the gear assembly (90) that actuates the drive wheel (70). A thrust bearing (83) supports the yoke (80) onto a mounting plate (46), wherein the mounting plate (46) is contiguous with a connecting joint (44) at the apexes of the triangular platform (41) as depicted in FIGS. 1–3.

The drive train for rotation about the "A—A" axis begins with a reversible drive wheel motor (72) and a drive wheel motor reduction means (73). An output shaft (74) is connected to the drive wheel motor reduction means (73), and may be coaxial with the control axis of the reversible yoke motor (81) and a reduction means (82). The output shaft (74) may emerge into the gear assembly (90) through the center of the yoke drive gear (84). The drive wheel drive gear (75) is rigidly connected to the output shaft (74) and engages a transfer gear (76). The transfer gear (76) may be connected by a drive shaft (77) through an intermediate bevel gear (78). The intermediate bevel gear (78) engages the drive wheel bevel gear (79) which rotates the drive wheel (70) about the drive axis "A—A."

The reversible yoke motor (81) rotates the yoke (80) and the drive wheel (70) about axis "B—B" through the reversible motor reduction means (82). The reversible yoke motor (81) and reduction means (82) may be substantially hollow along the central axis "B—B" to house the output shaft (74). Bidirectional torque output from the reduction means (82) drives the yoke drive gear (84). The yoke drive gear (84) engages a yoke idler gear (85). The yoke idler gear (85) engages teeth (86) which may be integral with the yoke (80), creating a torque that actuates rotation of the yoke (80) and the drive wheel (70) about the "B—B" axis.

The drive wheel motor (72), drive wheel motor reduction means (73), reversible yoke motor (81), and reduction means (82) may be rigidly and coaxially attached together. A face plate (67) mounts the motor/reducer assembly (95) to the mounting plate (46).

A number of electrical or optical cables (64) may connect the drive wheel motor (72) and the reversible yoke motor (81) with the power supply and also carry position information from angular encoders. This embodiment of an active roller (60) for a single roller about two perpendicular axes is advantageous because of the fixed position of the drive wheel motor (72) and the yoke motor (81). This fixed position allows use of a hard-wired cable harness rather than expensive and less reliable rolling or sliding electrical contacts.

FIG. 5 shows an alternative embodiment of the invention employing an active roller (160) which may have dual drive wheels (170). The two drive wheels (170) are driven by the output shafts (172). The output shafts (172) may engage an automotive type differential (174) which is connected to a gear assembly (190). A thrust bearing (83) directs loading against the mounting plate (46), which is formed as part of the connecting joints (44) as shown in FIG. 1. The motor/reducer assembly (95), as described for FIG. 4, is connected to the gear assembly (190), and works in the same manner as described in FIG. 4.

Using two drive wheels (170) for a single active roller (160) is more advantageous than using a single drive wheel (70) as shown in FIGS. 1, 2, and 4. First, the rotation of the two drive wheels (170) about their common center requires less energy input by the drive wheel motor (72) because the friction of rotation is reduced. Second, the typical curved path that the common center follows during actuation generates less friction and thus requires less energy input by the drive wheel motor (72). Third, the compressive loading at the contact points on the capsule (20) is half that of a single drive wheel (70) resulting in less wheel deformation of the capsule (20) and use of a thinner outer shell for the capsule (20).

FIG. 6 depicts another embodiment of the invention using a variation on the single drive wheel active roller system. In FIG. 6, a mounting plate (246) is integral to the connecting joint (44) as shown in FIG. 1 and rigidly supports both a reversible drive wheel motor (272) and a reversible motor (281). The drive wheel motor (272) and the reversible motor (281) may be mounted along two parallel but separate axis, "B—B" and "C—C". The drive wheel motor (272) may be connected to a gear assembly (290) so that the output from the drive wheel motor (272) rotates the drive wheel (270) about the drive axis "A—A". The drive wheel (270) is positioned about the "B—B" axis by the reversible motor (281). A spur gear (286) may be attached to the drive wheel housing (280) to the drive gear (284) which is connected to the output shaft (285) of reversible motor (281).

The invention preferably incorporates a vision system which the user views during motion. The vision system displays a scene on a monitor or a head mounted display wherein the viewed motion responds according to the motion of the user's vision. When using a head-mounted display, the display should shift when the user's head turns or tilts so that the user's experience parallels that of turning or tilting his or her head when viewing a real environment. For example, the displayed horizon will shift upwardly in the display when the viewer tilts his or her head downwardly. Position sensing is critical to coordinating vision with motion and the user's sense of real gravity. Consequently, both the position of the user's field of vision and the position of the capsule (20) itself are important in the present invention.

Position sensing may be accomplished by a variety of means. Rotational position may be sensed by a gyroscope mounted within the sphere, or by electrical coils interacting through electromagnetic induction. Linear position may be sensed by linear potentiometers, linear variable differential transformers, or magnetostrictive sensors mounted inside the actuator legs (48). Such systems are well known and well characterized by those in the art of motion sensing and control.

Motion control of the system may be either closed looped or open looped. A closed loop system senses the action being controlled and sends position information back to a controller so that the controller can minimize the error between the actual performance and the desired performance. An open loop system, however, does not send any position information back to the controller, and as a result, an open loop system does not automatically correct the error between the actual performance and the desired performance. Closed-loop motion control is preferred because it is more accurate. Both closed-loop and open-loop motion controls are established science, and a variety of theoretical and practical means are available for their implementation.

A preferred embodiment of the vision system may be a head-mounted display that sends separate images to each eye. Such a system creates a true three dimensional effect. Rotational motion on all three axes with respect to the ground is sensed at the user's head. Consequently, the user may tip his head and see a tilting landscape without causing the system to move. One such head-mounted display adaptable for use with the invention is the Eyephone HRX from VPL Research, Inc.

Another form of a virtual reality system useful with the present invention could include sound along with motion and vision. In a preferred embodiment, the sound system utilizes directional sound generation. Directional sound generation would allow the user's ears to perceive sound from different locations giving an indication of direction. One such system, the Convolvotron, has been dually developed by NASA's Ames Research Center and Crystal River Engineering, of Groveland, Calif.

The generally spherical capsule (20) is desirably free to fully rotate around the three orthogonal axes located at the center, the capsule has no direct physical contact with any external elements. Sliding contacts or hardwire cables are not particularly feasible in the embodiments depicted in FIGS. 1 and 2 because the data cable (227) shown in FIG. 3, for example, would interfere with the frame (40) as the sphere is rotated through certain angles or in certain directions. For example, if the user were to induce motions which would turn him or her upside down, such as in a simulated roll of an airplane, the cable system illustrated in FIG. 3 would tend to abut against the frame or the rollers. Consequently, data in the embodiments of FIGS. 1 and 2 must be exchanged between the capsule (20) and the external environment by electromagnetic means, as mentioned briefly above.

One such electromagnetic means may be a combination of multi-spectral digital laser pulses sending information into the capsule (20), and UHF radio signals sending information out of the capsule (20). For this communication configuration, a laser sending digital pulses aims its beam toward the capsule (20). A beam spreader widens the laser beam so that it projects the signal into a circular area called the "data circle." Laser-sensitive receivers (not shown) may be spaced evenly over the surface of the capsule (20) so that at least one receiver is within the data circle at any time. If necessary, these receivers may be flush with the rest of the surface of the capsule or be recess-mounted in the surface to

avoid any unwanted effects from contact with the rollers supporting and driving the capsule.

Inductive means, such as two wire coils, may be used to provide power inside the capsule (20), where direct connection of power is not feasible. Alternatively, quick-charge or replaceable batteries may be employed within the capsule (20).

In addition to the sensations of sight, sound, and movement, the instant invention may also operate on the basis of the user's sense of touch by using interactive solids. Interactive solids for use with the invention are contemplated as being either "passive" or "active". As used herein, the term "passive interactive solid" refers to a solid or semi-solid object which remains substantially stationary or is under the direct physical control of the user, while the term "active interactive solid" is used to refer to a solid or semi-solid object which can be moved by the virtual reality system in coordination with the electronic simulation of physical reality and physical input from the user.

Passive interactive solids are not connected to the interactive control means, and as such, move (if at all) only when physically acted upon by the user. Passive interactive solids may be used to impart the physical sensations of touch in fixed environments or corporeal objects that may be simulated by inanimate objects.

For instance, a passive interactive solid may comprise a mock-up of a control panel which remains fixed within the capsule regardless of the movements of the user or, in the case of simulated switches and the like, will move only when the user reaches out and physically moves the switch. Active interactive solids, in contrast, are moved within the capsule under the control of the virtual reality system and may take the form of a solid representing a wall which moves within the capsule as the user "moves" within the virtual environment. In an alternative embodiment having application in the emerging field of so-called "virtual sex," the visual images displayed for the user may be explicitly sexual in nature and the active interactive solids may be solids or semi-solids which represent an interactive partner in the "virtual sex" environment.

FIGS. 7–8 show an interactive support apparatus (100) which is a type of active interactive solid. In the present invention, the interactive support and apparatus (100) is a self actuated solid that moves in coordination with the virtual vision depicted on the head-mounted visual display (30) and in response to the physical contact of the user. The interactive support apparatus (100) may include a support arm (104) that is attached to the capsule (20). A back plate (106) may be connected to the support arm (104) and hingedly attached to abdominal support plates (108) by motorized hinges (107). Each abdominal support plate (108) may be attached to two first limb support plates (110), and each first limb support plates (110) may be attached to a single second limb support plate (112). The motorized hinges (107) may connect the abdominal support plates (108), first limb support plates (110), and second limb support plates (112), so that the user is sufficiently supported along all parts of his or her body.

Upon entering the capsule (20), the user may simply recline in the interactive support apparatus (100) and be strapped into place by the restraints (102) as shown in FIG. 7. The restraints (102) are preferably placed near major body joints. The user will preferably be further secured to the interactive support apparatus (100) by a shoulder harness and groin straps (not shown). The restraints (102) may be velcro straps, mechanically actuated rigid clamps, or any other suitable device.

The interactive support apparatus (100) ensures that the user is supported in a manner appropriate to both the actual physical environment and the manufactured virtual environment. While reclining, for example, a user is supported from beneath. An arm attached to first and second limb support plates (110 and 112, respectively) will be allowed to move freely above the virtual surface of reclination. Once the arm attempts to move through the surface of reclination, however, the support plates become rigid and the user's arm is prevented from passing through the virtual surface. In another example, a user may be suspended beneath the interactive support apparatus (100) and the first and second limb support plates may provide the sensation of moving a wing through the air as the user experiences flying like a bird in virtual space.

FIG. 9 depicts an alternative embodiment of an interactive support apparatus (100) which is capable of moving along three orthogonal axes within the capsule (20). In FIG. 9, the actuator arms (348) and translatable support arm (349) may all be connected on one end to the capsule (20) by rotatable connectors (355). The actuator arms (348) may be connected on the other end to the housing (353) of the translatable support arm (349) by rotatable connectors (355). The translatable support arm (349) may then be securely connected to back plate (106).

The actuator arms (348) and the translatable support arm (349) are depicted as cylinders that may be powered, for example, hydraulically, pneumatically, or electrically as ball-screw type actuators. Additionally, the actuator arms (348) and the translatable support arm (349) may be arranged as a tripod. One advantage to providing translation back and forth along three orthogonal axes within the capsule (20) rather than by moving the frame (40) as shown in FIG. 1 is that the components required for translational motion within the capsule (20) are smaller in size and do not require as much power. Moreover, the size of the capsule (20) will only need to be increased a nominal amount.

FIG. 10 depicts another type of active interactive solid for simulating walking. As the user's feet rise up and down, either a first platform (401) or a second platform (402) rise or fall to meet each step. Similarly, FIG. 11 depicts an active interactive chair. A seat platform (404) may move into position to act as a seat while a back platform (403) may move into position to act as a back. The active interactive solids depicted in FIGS. 10–11 allow a user to alternatively walk and sit upon a solid support while staying within the environment of the capsule (20).

FIG. 12 shows an interactive step (400) which moves with respect to the inner surface of the capsule (20). The interactive step (400) is also an active interactive solid. A linear actuator (405) may be mounted on two rotatable axis, "A—A" and "B—B". A foot pad (410) may be connected to the upper end of the linear actuator (405) and may be rotatable around axis "C—C" and "D—D". A first lower stepper motor (407) causes rotation about the "A—A" axis. Similarly, the second lower stepper motor (406) causes rotation about the "B—B" axis, the first upper stepper motor (409) causes rotation about the "C—C" axis, and the second upper stepper motor (408) causes rotation about the "D—D" axis.

In the virtual reality environment, the interactive step (400) may simulate stepping up a pathway by first using the lower stepper motors (407) and (406) to orientate the linear actuator (405) in the correct direction, and then the upper stepper motors (408) and (409) rotate the angle of the foot pad (410) to match the inclination of the expected terrain.

It is understood that a rotation about axis "A—A", "B—B", "C—C", and "D—D" may be accomplished by a variety of positioning means known to those skilled in the art of motion control. For example, any of the stepper motors may be replaced by a servo motor, plain DC motor, AC motor, hydraulic motor, pneumatic motor, or even a linear actuator. The linear actuator may be driven by hydraulics, pneumatics, or electrically. Alternatively, the foot pad **(410)** may be placed at the end of a two-part linkage with each joint angle precisely controlled as depicted in FIG. **10**.

FIG. **13** shows another type of active interactive solid, an interactive fluidic support apparatus **(500)**. The fluidic support suit may use either a gas or a liquid as the support medium. A pneumatic support suit **(501)** may support a user in a suspended state and uses a gas as the support medium. A buoyancy suit (not shown) may use a liquid as the support medium. In a pneumatic support suit, the joints **(505)** may be mechanically actuated to respond to the user's positioning requirements. For clarity, FIG. **13** omits depiction of the actuator means at the joints **(505)**, except as shown by the dual push/pull pistons at the left knee joint **(506)**. A linear actuator **(507)** may position the user's body in response to the user's positioning requirements.

The pneumatic support suit **(501)** may be attached to one end of the translatable support arm **(349)** and the other end of the translatable support arm **(349)** may then be attached to the capsule **(20)**. Two additional actuator arms **(348)** may be attached to the translatable support arm **(349)** by rotatable connectors **(355)** at the housing **(353)**.

The cross section of the pneumatic support suit **(501)** shown in FIG. **13** medium is shown in FIG. **14**. The pneumatic support suit **(501)** may use a rigid shell **(510)**. An air bladder **(512)** may be placed immediately adjacent to the rigid shell **(510)** on one side and a semipermeable layer of material **(517)** on the user's side. A semirigid porus layer **(518)** may then be disposed between surface of the user and the semipermeable layer **(517)**. Air input from a high pressure supply **(514)** may be regulated by the control valve **(515)** with integral pressure sensing. As the air enters through the control valve **(515)**, it inflates the bladder **(512)** to provide support to the user. The air then passes through the semipermeable layer **(517)** and into the highly porus region **(518)** where it may then be exhausted out of the system along the exhaust path **(519)**. The TiNi Alloy Company in San Leandro, Calif., manufactures a valve suitable for use as the valve on this application.

Relative and absolute positions of key external points of the pneumatic support suit such as the head, joints, feet, and center of gravity, may be calculated by kinematic means well known to those skilled in the art. Additional position information may be obtained by optical or sonic means.

The air pressure in bladder **(512)** varies according to the position of the user with respect to the bladder **(512)**. Position of the user may be sensed using a sealed chamber **(520)** which encloses a pressure sensor **(521)**. FIG. **15** shows a cross section of sensor location of the pneumatic support suit shown in FIGS. **13** and **14**, with three pressure sensors a first sensor **(521)**, second sensor **(541)**, and third sensor **(561)**. With the sensors spaced evenly at 120°, the position of the user's body may be determined continuously and accurately. If a supported segment of the user's body tends to go over to one wall of the suit and away from the other, one pressure sensing bladder is compressed while the other expands. For example, as pressure in the first bladder **(512)** increases, pressure in either the second bladder **(532)** or third bladder **(552)** may decrease giving direct indication of the position of the user within the rigid shell **(510)**.

Typically, the first sensor **(521)**, second sensor **(541)**, and third sensor **(561)** may be of the micro-machined solid state type available from a number of manufacturers. The invention permits attachment of the valves **(515)** and sensors **(521)** to the rigid shell **(510)** along the surface **(511)**. In the preferred configuration, at least three sensors may be mounted near every joint **(505)**.

In the present invention, an advantage of an interactive pneumatic support suit **(501)** with controlled joint action is that the suit can be actively employed to create the sensation of virtual solids. To create a virtual solid, pneumatic support suit **(501)** will allow motion up to, but not through the space occupied by a virtual solid. For example, contact with a solid such as a wall will cause the pneumatic support suit to lock up so the user cannot push beyond the virtual plane of the wall, creating the sensation of a solid wall in a particular location. Similarly, the user may experience virtual flying like a bird by having the rigid shell **(510)** of the pneumatic support suit move and vary the air pressure in the bladders to transfer the force of the rigid shell to the user to create the perception of drag and lift against a wing.

The interactive solids require a position sensing system for providing the correct position in coordination with the virtual environment depicted on the head-mounted visual display **(30)**. One example of position sensing system is described above in the description of the pneumatic support suit **(501)**. Another example of a position sensing system within the capsule **(20)** requires a combination of transmitters and receivers, where a number of receivers evenly spaced along the inside surface of the capsule **(20)** sense the position of a number of transmitters that are attached to various points of a user.

The transmitter and receivers used in the position sensing system are well known to those skilled in the art. For example, Logitech, Inc. uses an ultrasonic technique for determining position in their 2D/6D Mouse. As another example, one could use a magnetic position sensor such as that marketed under the name "Flock of Birds" by Ascension Technology Corp. of Burlington, Vt. The Flock of Birds system may be of limited use if power is supplied to the capsule by inductive means, as noted above. Also, the PLADAR (Pulsed Light Angle Direction Tracking And Range) tracking system by David Fenner of the United Kingdom uses LED transmitter-receiver couplings.

Using the PLADAR system, transmitters may be positioned at points on a user's body. Three receivers, having an open line of sight to each sensor, then accurately determine the point in space of each receiver by triangulating the relative signal strength between the emitter-receiver pairs as an indication of distance between the pairs. Consequently, the position of each transmitter may be determined and then processed to determine the position of the corresponding body part of a user. The active interactive solids can respond to a user's requirements for support, suspension, or free movement, by combining force sensing on the active interactive solid acting against a user and the position of the user's body parts as determined by a sensing system such as the PLADAR light-based system.

A sense of touch may also be achieved by taking advantage of the fixed nature of certain virtual experiences. Interchangeable passive interactive solids may be used to tailor the environment inside the capsule **(20)** to conform to a specific virtual experience. In the present invention, passive interactive solids have no means of self-actuation. Passive interactive solids are generally pre-formed shapes whose contours match those of the virtual environment, and

may be installed or removed quickly. Toggle-clamps or the like may be used to speed installation of a complete passive interactive solid environment.

One example of passive interactive solids involves a "mock-up" of the interior of an aircraft cockpit. In a cockpit, a pilot views the components of the cockpit's interior as fixed with respect to his position while the sky and earth appear to be moving. Pre-formed shapes whose contours match those of the virtual cockpit can be installed within the capsule (20) so that a user can press real buttons, grip a real control stick, and otherwise press against real solid surfaces corresponding to specific objects displayed in the virtual environment. Specific detail such as control gauges which respond to the actions of the user may be added virtually through the vision system.

FIG. 16 depicts one embodiment of a virtual environment including passive interactive solids. The user may recline in a fixed chair (430) which may be fastened to the inner surface of the capsule (20) by clamps (433). A control panel (440) may house a number of switches (443) which give an indication of being pressed. The control panel (440) does not house any dials or gauges, as those are represented visually through the head-mounted display (30).

By using passive interactive solids, the "reality" that the user experiences includes all of the elements of a fighter cockpit, for example, either through actual solid objects or virtual representations through the head mounted display (30). The passive interactive solids will allow the user to accurately sense pressing buttons and flipping switches and the like, and the system may respond as though the user is pressing real buttons.

An alternative or additional approach to interacting with passive interactive solids includes a sensing system for sensing the position of the user's lower arm and hand. Such a sensing system uses either light or ultrasonics, and may include an emitter (450) positioned near the users hand and a number of detectors positioned on the control panel (440) as shown by three detectors (455), (456) and (457). Position information may then be accurately determined and an image of the user's hand and arm can be coordinated into the image projected in the head mounted display (30). For example, a user will see his or her hand moving toward the control panel (440) and activating switches (443) when such a sensing system is employed.

Passive interactive solids are not limited to objects that define a fixed environment such as chairs and control panels. Passive interactive solids also include inanimate devices that passively simulate living beings such animals or humans. For example, a passive interactive dog may be used to impart the sensation of touch as a user pets a virtual dog, or a passive interactive human may be used to impart the sensation of physical contact. Of course, such objects could also be made as active interactive solids so that the dog or the partner move independently of direct physical contact with the user.

FIG. 17 depicts an alternative embodiment of a virtual system of the invention including a generally human-shaped interactive solid (691) simulating a human partner. The user (690) may wear a head-mounted display which displays the position and motion of the interactive solid (691) in virtual space exactly as the interactive solid is positioned in real space. This embodiment may be used for a variety of purposes, such as in teaching dancing lessons in a virtual reality environment, simulating wrestling, or in "virtual sex" applications.

The imagery corresponding to the interactive solid (691) may be completely generated by a computer; and as a result, the user (690) will have sole control over the virtual interaction. The imagery corresponding to the interactive solid (691) may also be generated by input from a second user (not shown) in a separate capsule (not shown). When the imagery is generated by a second user in a separate capsule, the interactive solid (691) is controlled by the second user and optimally is adapted to mimic the motions of the second user in the confines of the second capsule. Similarly, if the second user is interacting with a similar interactive solid in the second capsule, the second interactive solid will be controlled by the first user (690) and mimic that user's motions.

In FIG. 17, the user (690) may be supported by an interactive support apparatus (600) similar to the interactive support apparatus shown in FIG. 9. The interactive solid (691) may also be supported by an interactive support apparatus (600). An alternate embodiment of the interactive support apparatus (600) includes a rotation ring (650) for imparting complete rotation of the interactive solid (691) about the longitudinal axis of its torso. The rotation ring (650) permits a variety of interactive positions.

FIG. 18 depicts an alternative support apparatus (620) of the present invention for imparting greater freedom of movement to the interactive solid (691). The interactive support apparatus may include a linear actuator (624) which is movably attached to a positioning track (620). The positioning track (620) is mounted to the inner surface of the capsule at its ends. The linear actuator (624) moves the interactive solid (691) in and out along the longitudinal axis of the actuator. The movable contact of the linear actuator (624) along the arc of the positioning track (626) enables enhanced positioning of the interactive solid (691). A rotation ring (650) may be attached to the free end of the linear actuator to rotate the interactive solid (691) 360° about an angle relative to the longitudinal axis of a torso of the interactive solid.

FIG. 19 schematically shows operation of the rotation ring (650) permitting the user (690) or an interactive solid to move into alternate positions. The rotation ring (650) may include a fixed ring (655) which is rigidly connected to the linear actuator (653), and a moving ring (660) which engages the fixed ring (655) along its outer surface and support the user with its inner surface. The moving ring (660) rotates within the fixed ring (655) to permit the user a full 360° rotation or to impart a full 360° of motion to an interactive solid (not shown). Any suitable means known in the art, such as gear and motor assemblies or hydraulics, may impart the rotation to the moving ring (660).

FIG. 20 depicts an embodiment for a vehicular motion simulator. A lower hemisphere (22) is supportively abutted by the active rollers (60) that are connected to the frame (40) as described in FIG. 2. Four high frequency linear actuators (149) may be connected to the inside wall of the lower hemisphere (22) and connected to the four corners of a seat (126). The high frequency motion conveyed by the high frequency linear actuators (149) to the seat (126) simulates the high frequency vibrations of a vehicle traveling over a road. The low frequency motion of the vehicle such as cornering or acceleration may be provided by the actuators (148) and active rollers (60).

Given any data exchange format, a user inside the sphere may either be passive or active. A passive user might put a ROM disk into the CD disk drive, or interface with a cable television channel. The user might then be guided through an amusement park ride where such a ride would have nearly all of the characteristics of a real ride.

Alternatively, an active user might interface with a dedicated data link to a central node computer and participate in a continuous game involving many players operating in their own virtual reality environment at separate locations. These individual users will each share the same "virtual space" and could compete or otherwise interact as if they were in the same physical space. Such interaction may involve conversations or physical contact such as dancing.

The invention may also include other means for stimulating a user's senses such as smell, taste, and temperature. Since the capsule forms a closed environment, it is within the spirit of the invention to include stimulating all known senses.

Other types of interactive solid useful in a further embodiment of the invention are shown in FIGS. 21–39. FIG. 21 depicts an Omni-Directional Treadmill (ODT)(701) with an active surface (702) which employs a unique mechanism by which a user (703) positioned at any location on the active surface may be transported to any other point on that surface. Typically, a user who is headed off the active surface is moved back toward the center of the surface analogous to the way a linear treadmill prevents a user from running off the front or being flung off the back.

Integral to the ODT is a closed-loop motor control mechanism (704) and user position-sensing devices (705, 706) which pinpoint the position of the user (703) with respect to the fixed axes of the treadmill's active surface. These two work in concert with X axis control motor (707) and Y axis control motor (708) to ensure proper positioning of the user on the active surface, which is fixedly attached at selected points to a rigid base (709). In the embodiment of FIG. 21, the position sensors are ultrasonic transducers of a design well known to those skilled in the art of ultrasonic position sensing.

To address the problem of balance, the ODT optionally includes a means for steadying the user. A structure as simple as a circular railing may suffice. More preferable from the standpoint of transparency is the use of a balance cuff (710) which attaches near the user's center of balance. A hinge (711) at the small of the user's back connects the cuff to a support strut (712) which services to link the user with the X-Y tracking mechanism (713) of the support frame (714). Under normal circumstances, the cuff permits active X-Y tracking of the user because the support strut (712) actively maintains a vertical position. In this fashion, the user barely knows the cuff is there. When the user becomes unstable, however, the cuff serves to assist in regaining balance.

In order for the cuff and strut support to actively track the user in any orientation, the strut is preferably connected to a support structure (714) directly over the user's head which is supported by at least three vertical support members (715). Two motors (716, 717) actuate the X-Y tracking means respectively to maintain the support strut (712) in a vertical position with respect to the user. Motors are controlled by sensing the variance of the support strut from the vertical. A pair of X and Y potentiometers (718) sense the angular error of the support strut in the XZ plane and YZ plane respectively. An XZ error, for example, indicates that the X motor (716) must drive the mechanism in the direction to reduce the error to zero. Likewise for an error in YZ plane controlling the Y motor (717). Rotations about Z caused by the user turning are passed through a slip-ring assembly (719). Said slip-ring assembly prevents a winding or twisting of the support strut, and also permits passage of electrical power and signals through rotary electrical contacts so that connection may be maintained with the equipment worn by the user. Slip-ring assemblies are readily known to those familiar with rotary electrical contacts. In a similar fashion, the vertical motion of the user is permitted by an extension mechanism (720). Said extension mechanism allows only linear motion, and permits passage of electrical signals to and from the user.

The preferred embodiment of the device is a combined ODT/VR system as revealed in FIG. 21. It allows close coupling of the user's physical direction and velocity with that of the virtual world in which the user is navigating. Such a system might typically include a head-mounted display (HMD) (30) with speakers and microphone, data glove(s) (722), a body sensing suit (not shown), exoskeletal joint angle sensors, and/or other related apparatus. Said VR system would likely include a computer (35) for image generation, sound generation, and processing of related data such as head and hand position. Though not explicitly shown, peripherals worn by the user are hard-wire connected to the computer system through wires running up the support strut (712), through the X-Y tracking support (713), and down the support frame vertical member (715).

The ODT works in synchrony with the VR system by sending velocity and direction signals to the image generation computer. The computer uses the velocity vector thus provided to update the image which is shown to the user so that the user sees a visual image which takes into account this vector. For example, if the user's velocity is ½ meter/sec in the X direction as indicated by the X direction motion of the treadmill, the user will observe objects within the virtual world passing by at ½ meter/sec in the minus X direction.

Alternate embodiments of the combined ODT/VR system include the ability to tip the platform to stimulate uphill travel, and networked VR experiences in which one user shares a virtual world with others. Additional embodiments of the ODT/VR system include integration of sensing and stimulation systems. Examples of additional sensing systems might optionally include full or partial human surface mapping, video capture, or their combination, which can be manipulated and transported as the user's virtual image. A companion traveller in virtual space would then see a real-time facsimile of the user.

FIG. 22 is a block diagram for the control of a single motor. This motor and its affiliated control loop may actuate either the X or Y axis control for either the active surface or the support cuff tracker. With reference to FIG. 22, for a single axis of the active surface, the control signal is set for zero at the center of the surface. If the position signal is off-center, the summing junction generates an error signal which is proportional to the error. A PID (proportional-integral-differential) controller, which is well known and well characterized to those familiar with the art of motion control, is tuned to interpret the error signal over time, outputting a signal which controls motor velocity along one axis. Motor velocity and its associated direction are interpreted by the VR system as a velocity and a direction, and the image presented to the user is updated accordingly. Motor velocity also causes the active surface to be driven in a direction which reduces the error. The plant represents the system components, including the user, which are responsible for generating a position signal. In the instant case, the plant includes first, the active surface as it is driven back toward center; second, the user, who is being driven back toward center by the motion of the surface; and third, the ultrasonic transducers, which sense the absolute position of the user with respect to the zero reference position, and generate the position signal which may be resolved by the summing junction.

Control of a support cuff tracking motor occurs in a similar fashion. With reference to FIG. 22, the control signal is set for zero when the support strut is vertical with respect to its active axis. If the position signal shows an angle other than zero, an error signal is generated which is proportional to the angular error. The PID controller outputs a signal for the motor controlling the axis of interest, which turns at the specified velocity. The motor velocity drives the mechanism of the plant in the direction to reduce the error to zero, and the next cycle is begun. In the embodiment of FIG. 21, the position signal might be generated by a rotary potentiometer (718) which is affiliated with the axis of interest.

An alternative embodiment of the cuff support is shown in FIG. 23. The user (703) is shown wearing a harness (721) rather than a cuff (710) of the type shown in FIG. 21. In this case the harness is flexibly connected through a hinge (711) to a rigid horizontal member (730). Said member is hingedly connected to a vertical member (732), which is hingedly connected to a rotating fixture ring (734). Said ring is rotatably held within the base (724). In the section view, 23*a*, we see that the fixture ring is fastened to a gear ring (736) which rests on a dual bearing race (738) supported by a bearing ring (740). The gear ring is restrained from transverse movement by the bearing race grooves, and is constrained in the upward direction by roller contacts (742). Said ring is driven about its center by geared contact with a spur gear (744). The spur gear is driven by the drive motor (746) through a gear reduction means (748).

Shear sensors within the cuff (750) or at the hinge (711) generate a signal which is analogous to the error signal of FIG. 22. The motor (723) drives the ring in a direction to reduce the shear sensor output toward zero. In this manner the cuff and support struts track the user's position, providing support and balancing assistance to the user along with a hard-wired connection to the HMD and sound system. In all other respects, the active surface (702) of the ODT behaves the same as that in FIG. 21. For clarity, the position sensors, motor drivers, and computers are omitted from the figure.

An alternate embodiment would provide better support for the user by making the hinge support (752) of the horizontal member (730) and the hinge support (754) of the vertical member active members, i.e., they could be actively damped. Active damping would sense the rate at which the user is moving, and would increase damping in proportion to the velocity of movement. In this way, if the user should fall or lose his or her balance, the rapid change in velocity would cause much increased damping at the hinges, thus providing the support needed for the user to regain his or her balance.

A non-motorized embodiment of FIG. 23 would employ a hand grip for steadying balance, as shown in FIG. 24, rather than the actively tracking cuff of FIG. 21 or the harness of FIG. 23. The hand grip (760) attaches through a horizontal member (730) through a hinge (752) to a vertical member (732). The vertical member is attached through a hinge (754) to a rotating fixture ring (734) of the type depicted in FIG. 23 which is rotatably attached to the base (724). Because the ring rotates around the user (not shown) under power of the user, there is no motor. The user would always have at least one hand on the hand grip, and would apply forward and backward force, and torque to the handle to properly position it as he or she moved about the active surface (702). This embodiment of the invention, though reduced in features, would be less costly to manufacture and would require less ceiling height. The unit could be comfortably installed in the home or office with no special height or power requirements. For clarity, the user, position sensors and computers are omitted from the figure.

Haptic interaction may be accomplished through use of active or dynamic "interactive solids" also referred to generally as "haptic displays." FIGS. 25 and 26 show how such haptic display might interact with the user. FIG. 25 depicts a user in real space. Here we see the user (703) standing on the ODT (702), supported as before by a cuff and strut assembly (756). The user is reaching out and touching a flat, horizontal surface (758) upon which he is about to sit. Said surface is controllably placed by a motorized strut assembly consisting of a horizontal member (730), a vertical member (732), and hinge control motors (764, 766, 768). This positioning assembly is fixedly mounted on a secondary mounting ring (734) of the type first shown in FIG. 23. Said ring is powered and positioned by a motor (723) in a fashion similar to that of the motor depicted in FIG. 23. The surface of the haptic display (758) may be controllably placed by suitable rotation of the mounting ring (734) and turning of the hinge motors (764, 766, and 768).

FIG. 26 depicts visual reality as seen by the user of FIG. 25. In the virtual space of FIG. 26, the user (703) sees and physically interacts with the surface of FIG. 25 where it appears as a chair (772). This is an example of a dynamic interactive solid (also referred to as an "active interactive solid", above) because it may dynamically interact with the user to solidify the synthetic visual reality. A second chair (770) which is within the user's virtual world is also available to sit upon. If the user were to choose the second, lower chair, he would simply turn and walk to that chair. The ring (734) of FIG. 25 will swing the interactive solid (758) to correspond with the anticipated surface of the second chair (770), and the user may touch it and sit upon it.

In a similar fashion, a solid may be fixedly placed on the immobile base of the ODT. This example of a passive interactive solid performs the same function as a dynamic interactive solid, but has no ability to move or react to the user or the virtual environment. The image which corresponds to said passive solid is fixed in the reference space of both the real world and the virtual world. An example of said passive solid might be a desktop.

Passive and dynamic solids are not restricted to the circular-ring embodiments of FIG. 23–26. They may just as easily be implemented within the embodiment of FIG. 21 and its related variations. An example of such a hybrid system would include abovemounted cuff support, such as shown in FIG. 21, as well as single or multiple rings for positioning and securing passive and dynamic interactive solids.

The invention is not restricted to the use of a balance cuff. Omni Directional Treadmills with a larger surface and gentle centering actions may not need a cuff to support and balance a user. A large active surface area allows restorative forces to be gentle enough to avoid upsetting the user's balance.

Interactive solids are referred to in the literature as "haptic displays" or "roboxels". Related work has evolved interactive surfaces such as circular plates and shafts with torque feedback (Good, U.S. Pat. No. 5,185,561). Exoskeletal devices, such as those developed by Exos, Inc. and by Tachi in Japan, permit force feedback from shapes of arbitrary geometry. It is in the spirit of the invention to optionally include both passive and dynamic interactive, reality-enhancing means as integral to the function of the ODT.

By itself, the ODT is useful as an exercise device, a motion analysis device for movement in arbitrary directions, and a training device for lateral moves in arbitrary direction.

Combined with a VR system, the ODT is useful for exercise, motion analysis, training, recreation, virtual space navigation, telepresence, education, and psychological analysis and therapy.

In order for an active surface to move a resting mass in any direction, it must have available two active vector motion components, plus and minus X, and plus and minus Y. A linear treadmill has only plus and minus X. The ODT has both.

The ODT employs a "vector thrust drive" which mechanically separates the two motion components so that they can be powered and controlled by two separate motors. The vector thrust is the vector sum of the X motion component and the Y motion component.

As shown in FIG. 27, the active surface (780) of the ODT, hereinafter referred to as the roller belt, is comprised of a multiplicity of identical roller segments (781). A roller segment consists of a rigid shaft (782) upon which is mounted a freely rotating roller (783) which is kept within its lateral boundaries by spring clips (784) fastened at the ends of the shaft. Ends of the shaft are formed into eye hooks (785), which, in turn, are held around a common hinge axis by a hinge rod (786). Contact points of individual eye hooks are separated by spacers (787) to properly position them and to prevent lateral motion. Each roller fictionally abuts a surface (788), preferably a flexible belt, moving at right angles to the motion of the roller segments, along a line of contact (789) which serves to create selective rotational motion (790) to the roller. The flexible belt is supportively abutted by a rigid support plate (791) which substantially takes the load of the user's weight, and ensures that the active surface remains flat.

X-direction motion (792) of the roller belt (780) is driven by the X-direction motor (707) of FIG. 21. Y-direction motion (792) of the flexible belt (788) is driven by the Y-direction motor (708) of FIG. 21.

FIG. 28 shows the complete mechanism for achieving full omni-directional motion, and shows that the hinge rod (801) permits the roller belt (802) to flex around rollers (803, 804) at the belt edges. Hex rollers actuate the roller belt in the plus and minus X vector direction (805). As shown, rollers are hexagonal in shape to accommodate the hinged nature of the roller belt.

In the embodiment of FIG. 28, one hex roller is powered by a motor (806) while the other is an idler (807), although both rollers could easily be powered. The linearly actuated planar surface (808), which is the top surface of a flat, closed-loop drive belt (809) is placed in intimate contact with the bottom surface of the roller belt (810), and oriented so that its motion is at right angles to the motion of the roller belt. It is supported and directed at its ends by rollers (811, 812). In the preferred embodiment, only one roller is actuated by a motor (813); the other is an idler roller.

Rollers are supported by bearings (814), or by a motor drive shaft (815). The bottom surface of the flat, flexible drive belt (809) is supportively abutted by a rigid support plate (816) which is supported at each of its four corners by support legs (817). Said support legs, bearings, and motors are securely fastened to a rigid support surface (818) which serves as ground.

When the roller belt alone is actuated, the top of the rollers provide plus and minus X motion. When the flat belt alone is actuated, it fictionally contacts the bottom surface of the rollers, thus causing them to rotate about their free axis. So, if the belt is moving in the -Y direction (819), the top surface of the rollers is moving in the +Y direction (820). Since the contact lines at the top of each roller are moving in concert, a mass resting on the active surface (821) defined by the sum of the contact lines is moved in the direction of the combined X and Y motion vectors. The active surface of this figure (821) may be identified with the active surfaces of FIG. 21, FIG. 23, and FIG. 24.

By actuating the beaded belt and the flat belt simultaneously, the surface contact lines of the rollers may be made to impart any combination of X and Y movement. For instance, in FIG. 29 we see a roller segment (830) moving at plus 1 foot/second in the X direction (831), and the flat belt (832) is moving at minus 1 ft/second in the minus Y direction (833). The freely-rotating roller converts the belt's -Y motion to a +Y motion at the contact line (834). And the combined thrust vector (835) equals the vector sum of the two belt's motions, i.e., 1.414 ft/second at an angle of 45 degrees in the first quadrant.

For better stability, the underside of the flat belt is supported by a smooth, flat, rigid surface (836). The interface surface between the flat belt (832) and the support surface (836) is preferably reduced in friction by coating with a slippery substance such as teflon.

A tensioning mechanism is advantageously employed on one of the two rollers in the X direction and one of the rollers in the Y direction, preferably the idler roller, so that any slack or relaxation of the belts may be taken up.

Rollers may be arbitrarily small or arbitrarily large. However, sensible limits are placed on roller size by factors such as ease of assembly. In addition, the size of the hexagonal rollers is determined by the length of the roller and the hinge segment it defines. Obviously, there is an optimal roller size range for said assembly.

A hexagon shape has been arbitrarily chosen to depict the roller belt actuation means. The roller is not restricted to this shape, though it is reasonably expected that the roller will have between six and eight sides to optimize the balance between size and manufacturability.

The vector-slip principle may be employed with discrete components of another form as well. In FIG. 30 is seen one corner of the active surface of the ODT (841), which consists of a multiplicity of identical beaded segments (842). A beaded segment consists of a flexible cable (843) upon which is strung a number of beads (844). The cable is fastened end to end to form a closed loop. Beads are separated by spacers (845). Spacers serve two purposes. First, they ensure a uniform bead spacing. Second, they impart linear force to the bead as the cable is pulled in either direction. Without the spacers attached to the cable, the cable would tend to pull through the beads rather than force them in the desired direction.

Rollers (846) (only one shown) support and direct the return loops (847) at the segment ends. Adjacent segments are fastened to each other by the spacer mechanisms (845). The combination of adjacent bead segments and their associated spacers forms a uniform surface of beads, which is directly analogous to the uniform surface of the roller belt. As with the roller belt system, said beads are actuated in the plus and minus X direction by one set of rollers, and are actuated in the plus and minus Y direction by contact with a flat belt (848).

Rather than stringing components on wire and fastening them together, it is also possible to fabricate a single, repeating construction unit which accomplishes the same function as the wire and bead assembly of FIG. 30. FIG. 31 depicts such a repeating unit. A bead (901) (or roller) is rotatably mounted on a shaft (902) which has a male (903)

and female (904) end as well as a connecting strut (905). Beads are connected into closed-loop strings by fastening the male portion of the assembly into the female. Connections between strings of beads are made by mounting the hole of the strut (906) over the male portion of the adjacent string. It is understood that said repeating, componentized structures are also suitable for construction of a roller-type unit which duplicates the function of the roller belt described in connection with FIG. 30.

Following assembly of all the bead segments which comprise a roller belt, the assembly will look much as that depicted in FIG. 30, except the spacers (845) will be an integral part of each unit assembly as separate connecting struts (905).

FIG. 32 reveals yet another embodiment of an omnidirectional surface actuation means which uses a wheel (1001) with idler rollers (1002) positioned around its circumference. An idler roller unit (1003) is inserted into the appropriate receptor notch in the wheel (1001). Each idler axis (1004) is oriented perpendicular to the powered axis (1005) of the wheel. Said vector-slip wheel has the unique property of being able to transmit force only through a line perpendicular to the powered axis (1006), the X axis. Any motion which the wheel sees in the Y axis passes over the idlers (1007).

FIG. 33 shows that by combining the above-described vector-slip wheel of FIG. 32 in an array of X oriented wheels (1101) and Y oriented wheels (1102), a combined direction vector may be achieved by selective actuation of the X and Y arrays. Said wheels are actuated in the Y direction by one set of belts (1103), and in the X direction by another set of belts (1104) which contact the bottoms of the wheels. These belts are held and directed by a base (1105) with guide grooves and mounts for the wheel arrays. Wheel (1001) is a typical X-direction wheel of the construction of FIG. 32. It is held onto the base by snap fitting its axle (1107) into snap grooves of a pair of mounting posts (1108), where only one post is shown. Every wheel is held onto the base in the same manner.

Because the X wheels are a larger diameter than the Y wheels, the X-contacting belt and the Y-contacting belt do not come into contact with one another. As with the beaded invention, actuation of the X wheel array actuates motion in the plus and minus X direction which passes easily over the idlers of the Y vector-slip wheels with no hinderance. Pure Y motion is likewise unhindered by the X array. As long as a resting mass contacts a reasonable number of X and Y rollers, combining X and Y wheel arrays permits an active surface which is able to linearly actuate the resting mass in any direction through combination of the X and Y vectors.

Drive belts (1103, 1104) are continuous belts which are driven by rollers (not shown). The rollers are powered and controlled by motors in a fashion similar to the roller/motor combinations of FIGS. 21–24 & FIG. 28.

Ergotech, Inc. makes an assortment of large rollers which employ shaped idler pulleys on their exterior which fall into the same class as the vector-slip wheel. Their use is as passive moving devices for boxes and other flat-bottomed articles.

Martin-Marietta has employed a vector-slip drive on a lunar rover. Their idler rollers are oriented at 45 degrees to the main wheel drive axis. Thrust is therefore always at 45 degrees to the main wheel drive axis. By proper combination of the four thrust vectors available from the four wheels, the rover is able to navigate in any arbitrary planar direction.

One advantage of the method of discrete construction units is that their hinged nature allows better control of the active surface topography. By making the material of the flat belt flexible and deformable, and by supporting the underside of the flat belt with a multiplicity of individually controllable idler rollers, each support point may be selectively raised or lowered. By selectively raising or lowering the idler support points on the flexible underside of the flat belt, and by jointedly connecting discrete construction units to form the beaded active surface, the active surface may be deformed with controllable bumps and depressions. Said bumps and depressions might be advantageously shown as matching bumps and depressions in the virtual environment, thus enhancing the reality of the immersive experience.

In a comparable fashion, the vector-slip wheels of FIGS. 32 & 33 may be individually raised and lowered to simulate a surface of varying texture. Since the vector-slip wheels are discrete units rather than tied in to a belt, they may be raised and lowered substantially more than their roller or bead counterparts. In this embodiment, because vector-slip wheels are potentially decoupled from their support surface, it is no longer possible to drive them using belts as shown in FIGS. 33. Each wheel must be individually actuated using separate drive means. While more complex, this embodiment is the only one of the aforementioned systems which permits simulation of complex tasks such as climbing stairs while retaining the advantage of ODT.

FIG. 34 reveals yet another embodiment of an ODT which employs a moveable, continuous, active surface (1201) that wraps around a flattened spheroid (1202). Said active surface is held onto the surface of the spheroid by its own elasticity, and the contact zone between the rigid spheroid and the moving surface (1203) is relatively frictionless. By sliding the active surface around the spheroid, the flat portion at the top of the spheroid (1204) will serve the same function as the active surface of earlier figures.

FIG. 35 is a cross section of the fully implemented spheroid construction of FIG. 34 the ODT (1301) shows an active surface (1302) which stretchably surrounds the rigid spheroid (1301), separated by a relatively frictionless layer (1304). The housing (1305) retains the active surface and spheroid by mounting passive casters which substantially retain the top (1306) and bottom (1307) contours of the fundamentally spheroid shape, and by presenting a slight overhang to retain motion of the assembly in the upward direction.

The active surface is controllably actuated by frictional contact with a steerable roller (1308). Said roller is steerable about two axes. Axis one (1309) is powered by a motor (1310) about the roller itself, thus driving the bottom side of the active surface by a frictional contact. Axis two (1311) drive by motor (1312) provides steerability of the roller so that the roller can direct its thrust vector in a full circle. A thrust vector provided by the roller causes the active surface to slide around the spheroid. As depicted, with the roller providing thrust on the lower surface substantially in the plus X (1313) direction, the upper surface responds in the minus X (1314) direction.

FIG. 36 details a potential embodiment of a small area of the active surface (1401). A pattern of rigid plates is arranged to form an array of hexagons (1402) and pentagons (1403), much like the surface of a soccer ball. Corners of the plates are held together elastically (1404), so that the surface may expand and contract appropriately as it traverses the spheroid. The underside of each plate is suitably supported by an arrangement of casters (1405) which are pressed into the rigid material of the plate. Said casters permit contact between the plate and the spheroid to be low in friction, as required for proper function.

An improvement on the embodiment of the powered roller (**1308**) of FIG. **35** would be to split the roller function into two rollers actuated by a differential gear unit. It may still be powered by two motors as revealed above, however it would gain the advantage of minimizing rotational friction during steering, in much the same way an automobile differential permits the drive wheels of a turning car to rotate at their own speed.

It is understood that the surface construction of FIG. **36** is exemplary, and represents only one of a class of surface constructions which fulfills the function of a flexible, low-friction active surface interacting with a contained, flattened, spheroid.

Although the basic system configuration includes a support cuff for assistance of balance and optionally for tracking user orientation, it also has the potential to completely lift and support the user. A strengthened and fully actuated support strut connected to a fully supporting cuff and harness enables a user to be lifted up from the active surface and moved within the confines of the mechanically limited motion envelope. A system of this type would allow a user to transition between active surface locomotion and free-body flight.

In a similar fashion, the entire active surface and related mechanism may be mounted upon a motion platform which permits various combinations of linear and angular motions of the surface. A tipped surface is useful for simulating an inclined surface in virtual space, like a user might encounter when walking up a virtual hill. A surface which moves up and down as well as angularly can simulate the deck of a ship, or the cabin aisle of an aircraft.

FIG. **37** depicts the combination of the simplified ODT of FIG. **24** (**1501**) with a standard 6 degree-of-freedom hexapod motion platform (**1502**). The base of the ODT (**1503**) serves as the attachment point for the six linear actuators (**1504**) which comprise the hexapod. Control of said cylinders provides full **6** DOF motion, and the control of said hexapod structure is well known to those skilled in the art of motion control. Cylinders are attached by ball joints (**1505**) to the ground, and by ball joints to the base (**1503**). Said cylinders may typically be actuated by hydraulics, pneumatics, or by a ball screw mechanism. The power and control means for the hexapod and ODT are omitted from the figure, but are understood to include a power conditioning means, a position sensing means, a control computer, and a control loop of the type described in FIG. **22**. It is also understood that the ODT which attaches to the hexapod might just as easily be of the construction of FIGS. **21, 23, 25, 30, 33, 34**, or **35**.

Combining the ODT with an enclosed simulator such as the spherical motion environment discussed above in connection with FIGS. **1–20** would permit not only 3 to 6 degrees of freedom motion to be applied to the active surface of the ODT, but would also allow transitioning between waling, free-body flight, and vehicular simulation.

An ODT need not be the main interface device for an immersive system. It might, for example, be complimentary to a vehicle simulator. A standard simulator for a vehicle such as a jeep, mounted on a hexapod motion platform, could be placed adjacent to an ODT. As the user emerges from the vehicle simulator, the ODT would be positioned at virtual ground so that the user experiences a smooth transition between vehicular transport and ground motion.

The unique, omni-directional qualities of an active surface such as those revealed herein may be employed in yet another way. As a haptic display device, an active surface is able to convey a sense of friction to a user as they run their hand along a surface. FIG. **38** presents an embodiment for an active-surface haptic display (**1601**). As the user's hand (**1602**) reaches out to contact a virtual object, the active surface (**1603**), which is only slightly larger than the major diameter of the user's palm print, is placed by a robotic mechanism (**1604**) where the user expects that surface to be. As the user moves their hand along the surface in one vector direction (**1605**), the haptic display mirrors the motion of the hand (**1606**), while the active surface creates an equal and opposite counter vector (**1607**) by moving its surface counter to the motion of the hand. The user resultingly feels the friction of the virtual solid's surface as the hand is rubbed across the moving surface. Because of the omni-directional nature of the active surface, the hand may trace an arbitrary path.

In its basic embodiment, the active surface is flat both because the support surface behind the activation means is most easily fabricated as a flat surface, and because the interlinked nature of the active means tends to prevent creation of surface contour. A flat surface will be effective for simulating a flat virtual solid, but it can only approximate a curved solid. A moderate amount of curvature may be achieved, however, by bowing the support surface upward. In the case of haptic display using an active surface, bowing might be accomplished using pressurized air behind a thin and flexible support surface. The amount of bowing may be controlled to correspond to the average curvature at the user's contact point with the virtual solid.

Description of the preferred embodiment as including an HMD, gloves, body suit, etc. does not exclude other applicable system configurations. There are a number of additional display options which may advantageously employ an ODT. For example, a display method may surround the user with large display screens. Spherical display surfaces have been employed for a number of years by various companies such as IMAX theater, or Evans & Sutherland, Inc. Most recently, Evans & Sutherland, Inc. revealed a spherical viewing structure which essentially surrounds the user to provide a nearly fully spherical viewing surface. A projected image tracks the user's viewing cone and displays the appropriate scene. An advanced display method being developed by the Human Interface Technology Lab places light directly on the retina of the eye using a weal laster beam. Any of these display systems and their related interfaces can benefit by use of the ODT.

Discussion of a VR system would not be complete without mention of telepresence. While VR systems substantially synthesize the user's sensory experience, telepresence systems extract their sensory information from a real, remote source and convey it to the senses of the user. In the simplest example, a pair of video cameras might be mounted on a 3 degree-of-freedom platform whose motion is slaved to the user's head. An HMD on the user's head receives the stereo images from the paired video cameras thus creating the visual illusion that the user's head is sitting on the platform instead of the two cameras! A system is this type which also includes sound is commercially available from Telepresence Research, Inc.

With regards to the ODT, it is feasible to couple the walking motion of the user to the lateral movement of a remote sensing device. Using natural walking and turning motion to steer and guide a remote device has the advantage of freeing both hands to perform other tasks rather than being restricted to a steering device like a joystick. A coupling of the telepresent remote with the user would likely include, besides the ODT, a video and sound link. Other

system configurations might include one or two hand operated actuators which the operator uses to perform manipulation tasks at the remote site.

FIGS. 39a and 39b show a system in which a user at one site (FIG. 39a) controls the remote at a distal site (FIG. 39b). This advanced form of ODT and telepresent coupling would employ not only the above-mentioned systems, but also a means of conveying the remote's physical orientation. This is accomplished by using the balance cuff (710) to force the user (703) into the orientation (1703) of the remote (1704). Feedback on the cuff by the user, in turn, also forces the remote into the orientation of the user. By combining this orientational interplay with a bipedal remote and an exoskeletal structure (1705) which links the remote's legs to the user's legs, it is possible for the remote to balance itself in both standing and walking modes. Combination of the above structures to enable locomotion of the remote is made possible because the user is standing on an ODT active surface (702) which permits the user to employ their natural balance abilities as they navigate using the electronic eyes of the remote.

According to the provisions of the patent statutes, we have been explaining the principle, preferred construction and mode of operation of our invention and have illustrated and described what we now consider to represent its best embodiments. However, it should be understood that within the scope of the intended claims, the invention may be practiced otherwise than as specifically illustrated and described.

What is claimed is:

1. A motion simulating device, comprising:

a capsule adapted to receive at least a portion of a user therein;

at least three rollers carried by a frame and supportively abutting the capsule, wherein the capsule is supported solely by the rollers and at least two of the rollers are active multi-directional rollers for rotationally driving the capsule with respect to any of three orthogonal axes located at the center of the capsule; and

a means for interactively controlling the motion of said capsule and said frame.

2. The motion simulating device of claim 1, wherein the interactive control means comprises:

a visual display;

a means for sensing the position of said capsule;

a means for coordinating the motion of said capsule and a representation of motion on said visual display; and

a means for controlling the motion of said capsule responding to a representation of motion of the user on said visual display.

3. The motion simulating device of claim 2, further comprising:

a means for sensing the position of a user within said capsule;

a means for coordinating the motion of a user and a representation of motion on the visual display; and

a means for controlling said interactive solids responding to a representation of the motion of a user on visual display.

4. The motion simulating device of claim 1, wherein the frame comprises:

plurality of beams;

a plurality of connecting joints, each rigidly attached to two of said beams; and legs, each connected on one end to one of said connecting joints and on the other end to a supporting surface.

5. The motion simulating device of claim 4, wherein said connecting joints further comprise:

beam receptacles, each fixedly attaching one end of said beams to said connecting joint; and

a mounting plate for fixedly attaching one of said rollers to said connecting joint.

6. The motion simulating device of claim 4, wherein said actuator legs further comprise a means for changing the length of said actuator legs.

7. The motion simulating device of claim 6, wherein said means for changing the length of said actuator legs further comprises a hydraulic cylinder for telescoping a movable rod along the longitudinal axis of a support housing.

8. The motion simulating device of claim 6, wherein said means for changing the length of said actuator legs further comprises a ball screw for telescoping a movable rod along the longitudinal axis of a support housing.

9. The motion simulating device of claim 4, wherein said actuator legs are each rotatably connected on one end to one of said connecting joints and on the other end to a supporting surface.

10. The motion simulating device of claim 1, wherein at least one of said active rollers comprises:

a drive wheel rotatable about a drive axis generally parallel to a tangent to the surface of said capsule and frictionally engaging said capsule; and

a yoke for orienting the drive axis with respect to said capsule, said yoke being pivotable about an axis generally perpendicular to the drive axis.

11. The motion simulating device of claim 1, wherein there are only three rollers supportively abutting the capsule and one of said rollers is passive.

12. The motion simulating device of claim 1, further comprising active interactive solids connected to the interior of said capsule for imparting sensations of force directly upon a user.

13. The motion simulating device of claim 12, further comprising a translatable support arm.

14. The motion simulating device of claim 12, further comprising:

a support arm;

a back plate attached to said support arm;

abdominal support plates hingedly connected to said back plate;

first limb support plates hingedly connected to said abdominal support plates;

second limb support plates hingedly connected to said first limb support plates;

a means for positioning said abdominal support plates, said first limb support plates, and said second limb support plates, about the hinged connections; and

a means for securely restraining user to said back plate, said abdominal support plates, said first limb support plates, and said second limb support plates.

15. The motion simulating device of claim 14, wherein said support arm is translatable.

16. The motion simulating device of claim 1 further comprising a treadmill mounted within the capsule, the treadmill having a track assembly comprising a user support movable in a first direction for supporting a user, said user support including a plurality of support members rotatable about axes generally parallel to the first direction; a first driver connected to the user support means to move the user support in the first direction; and a second driver cooperating with said support members to rotate said members, whereby

the combined movements of the user support and the support members results in movement of the user on the user support in a second direction.

17. The motion simulating device of claim 16 wherein the user support comprises a pair of cylindrical members, at least one cylindrical member being connected to one of the first and second drivers to rotate the one cylindrical member; an endless belt trained about said cylindrical members moveable by the one cylindrical member in said first direction, said endless belt having rods for rotatably supporting the user support members for rotation about axes generally parallel to the first direction.

18. The motion simulating device of claim 17 wherein the second driver comprises a pair of rollers and an endless belt trained about said rollers, said second driver being connected to at least one of the rollers to move the belt; said belt having a top surface operably engagable with the user support members to rotate said support members.

19. The motion simulating device of claim 18 wherein said endless belt has an upper run defining the top surface, further comprising support means located below said upper run for folding the upper run in contiguous relationship relative to the user support members.

20. The motion simulating device of claim 16 wherein the user support includes rods and the user support members are cylindrical sleeves rotatably mounted on the rods.

21. The motion simulating device of claim 16 wherein the user support includes a plurality of longitudinal rods and the support members comprise spherical members rotatably mounted on the rods for rotation about the longitudinal axes of the rods.

22. The motion simulating device of claim 16 further comprising a virtual reality apparatus, the virtual reality apparatus comprising

a first display mountable on a person's head for displaying visual images;

a display control means for projection of an image;

a speaker for generating sounds;

a microphone;

means for sensing the position of the person on the support; and

means connected to the first display, display control means and speaker for generating images and sounds.

23. The motion simulating device of claim 22 further comprising interactive solids for providing the person with haptic feedback.

24. A motion simulating device having an active interactive solid for use in conjunction with a virtual reality display, comprising:

a controllably movable physical medium having a sufficient substance for imparting the desired motion upon a user, the medium comprising an interactive support apparatus including a support arm and an interactive pneumatic support suit attached to said support arm; and

a means for interactively regulating the motion of said physical medium for regulating the amount and direction of force applied upon a user.

25. The motion simulating device of claim 24 wherein the support arm is translatable.

26. The motion simulating device of claim 24, wherein said regulating means further comprises:

a means for sensing the position of a user;

a means for coordinating the motion of a user and a representation of the motion of the user on a visual display; and

a means for regulating said controllably movable physical medium responding to a representation of the motion of the user.

27. The motion simulating device of claim 24 wherein the support arm is translatable, the interactive pneumatic support suit being attached to an end of the support arm.

28. A motion simulating device, comprising:

a generally spherical capsule;

a translatable frame for supporting said capsule, the frame including a plurality of beams, a plurality of connecting joints each rigidly orienting two of the beams, a plurality of actuator legs each rotatably connected on one end to one of the connecting joints and on the other end to a supporting surface;

a plurality of rollers mounted to the connecting joints supportively abutting the capsule, and at least one of said rollers comprising an active roller, wherein the active roller comprises a drive wheel rotatable about a drive axis generally parallel to a tangent to the surface of said capsule and frictionally engaging said capsule, and a yoke for orienting the drive axis with respect to said capsule, the yoke being pivotable about an axis generally perpendicular to the drive axis;

an interactive user support apparatus including a translatable support arm connected to an interactive pneumatic support suit; and

a means for interactively controlling the motion of said capsule and said frame, the interactive control means including a visual display, a means for sensing the position of said capsule, a means for coordinating the motion of said capsule and a representation of motion on said visual display, a means for sensing the position of a user within said capsule, a means for coordinating the motion of a user and a representation of motion on the visual display, a means for controlling the motion of said capsule and at least one interactive solid responding to a representation of motion of the user on said visual display.

* * * * *

March 21, 1967 W. HELMORE 3,309,795

MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES

Filed July 12, 1961 4 Sheets-Sheet 1

Fig. 1.

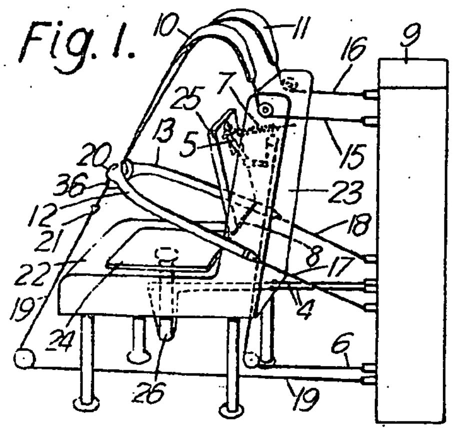


Fig. 2.

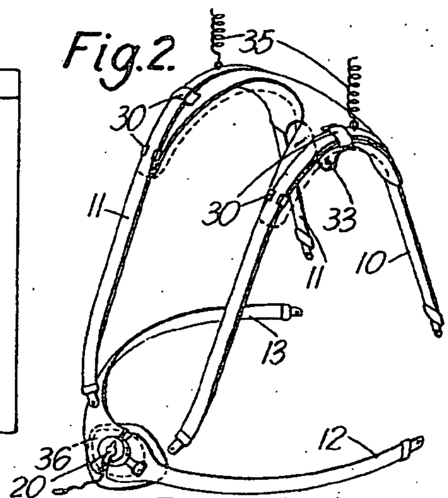
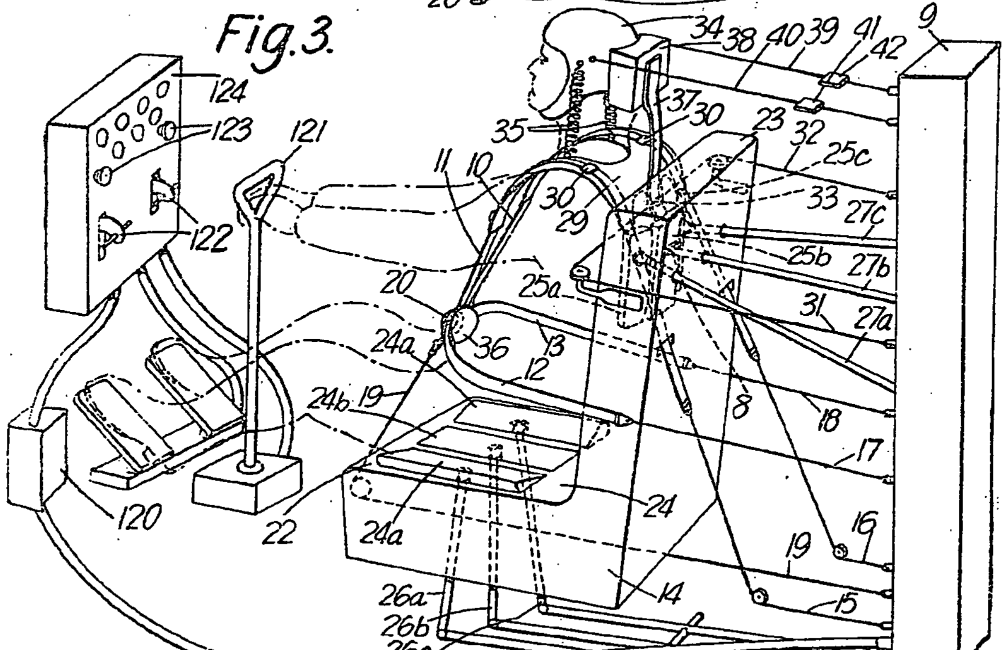


Fig. 3.



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MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES

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Fig. 4.

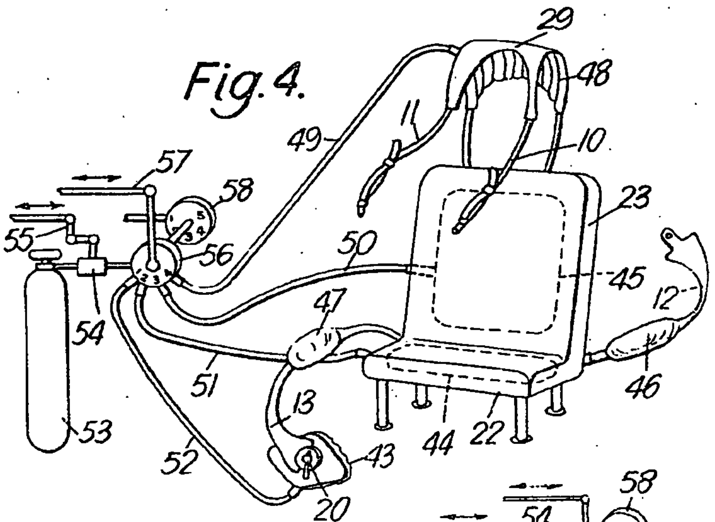
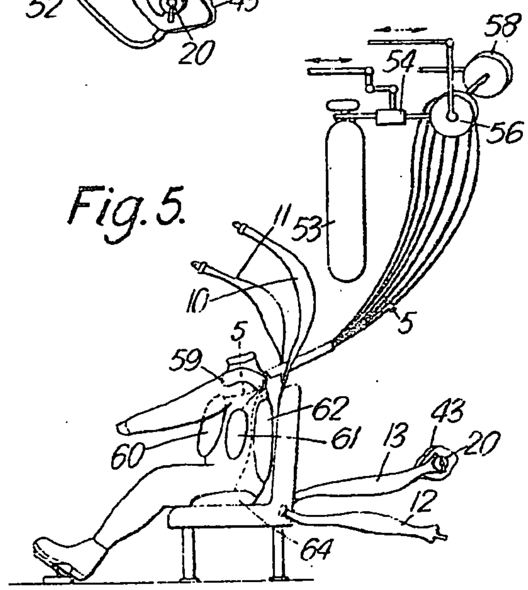


Fig. 5.



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MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES

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Fig.6.

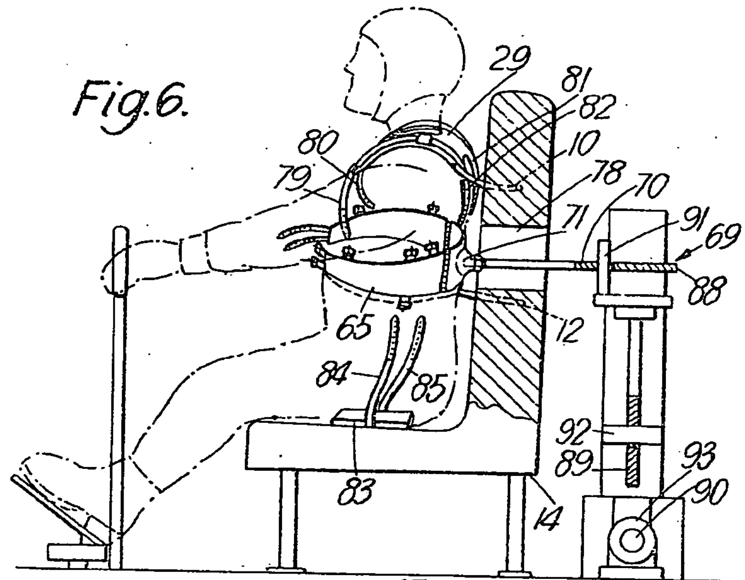


Fig.7.

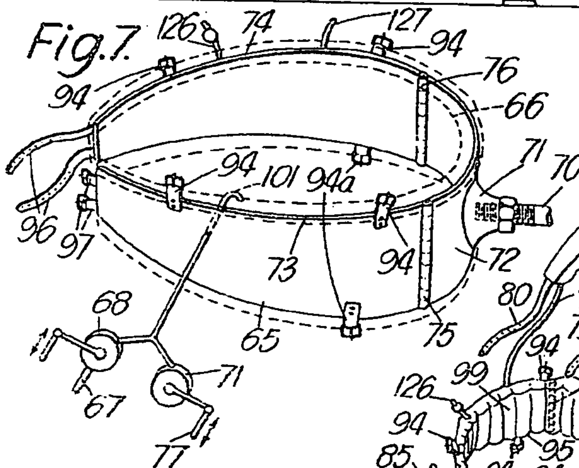
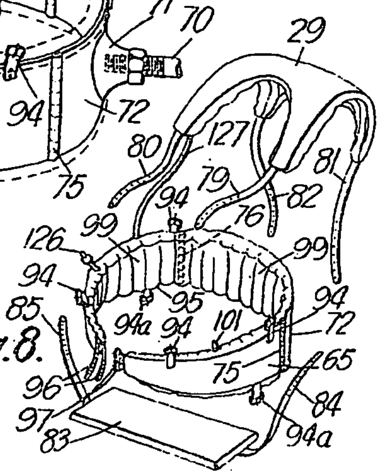


Fig.8.



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MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES

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Fig. 9.

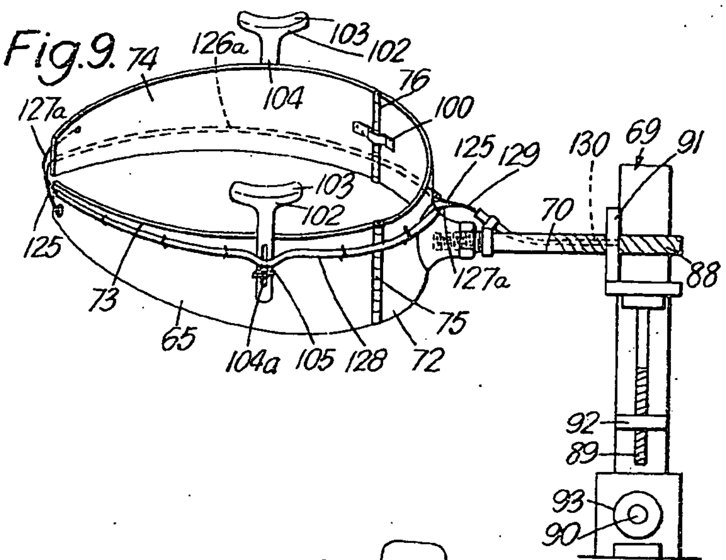
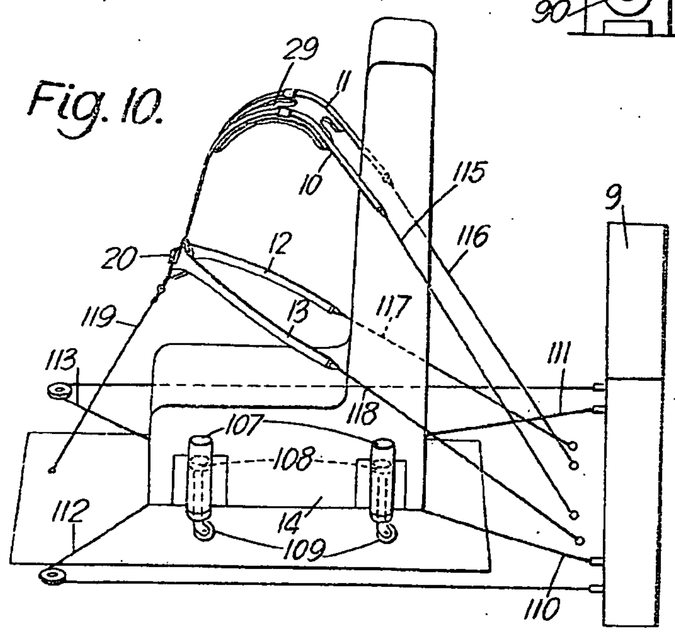


Fig. 10.



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MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES

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Claims priority, application Great Britain, July 13, 1960, 24,491/60
21 Claims. (Cl. 35—12)

This invention relates to flight simulators and to apparatus designed for the instruction of pupils in the control of aircraft and other vehicles.

It has previously been proposed in flight simulators employed for this purpose to provide a substantially stationary reproduction of the cockpit controls instruments and other environment of the aircraft it is desired to simulate and also to provide for limited changes in attitude of the aircraft in relation to its fore and aft and lateral axes together with some limited movement of the simulator as a whole. Such simulators, however, do not sufficiently impose upon the body of the pupil a sense of the very great changes of momentum occasioned in an aircraft by changes of course, attitude and velocity when actually in flight and thus the training of the pupil is deficient in this important respect.

In actual flight, change in velocity (i.e. acceleration) and in direction of flight of an aircraft are transmitted to the pilot's body, for the most part, through the chair, which is usually fixed to the aircraft, and through the pilot's harness which is attached to the chair; thus owing to the momentum or inertia of the pilot's body at any instant of time such changes in the flight of the aircraft will result in some small relative movement between the pilot's body and the chair and/or harness which movement is restrained by these latter parts and the pilot will experience pressure from them on different parts of his body until his body attains the same velocity and direction of flight as the aircraft. However, as different parts of the human body have different masses and thus different inertia, the pilot will experience not only restraining forces and pressures on different parts of his body from the chair and harness, but also sensations from the different inertia effects on the various parts of his body and those effects are mainly felt in the region of the stomach. The object of the invention is to simulate or reproduce these various effects on a pilot in known training apparatus.

According to this invention a flight simulator comprises a chair mounted upon a support, equipment to be worn by the pilot, power means for imparting relative movement between parts of the said equipment and the chair so as to apply pressures and movements to different parts of the pilot's body such as would be produced by changes in flight conditions due to the inertia of the pilot's body.

The power means may be mounted on a fixed part of the apparatus and may be provided with a number of differentially movable actuating members connected to different parts of the equipment.

The said power means and differentially movable actuating members may have associated therewith control means adapted to be actuated by the pilot in operating his flight and engine controls and/or in adjusting his instruments, or by the instructor or by time controlled means, for example a servo-motor, potentiometer and computer means may be embodied in said controls.

In such an arrangement certain of said actuating members are adapted to impart fore and aft movement to the back of the chair and to apply and release pressure on the pilot's abdomen and to apply up and down movement

to the seat of the chair relatively to other parts thereof, downward movement to the shoulders and sideways movement of the pilot's body.

In this last arrangement the equipment may comprise two shoulder straps connected at one end to two of said actuating members so as to impart downward movement thereto and at the other end to the centre of a belt which is connected to another of said actuating members to impart also downward movement thereto and the ends of which belt are connected respectively to another two actuating members so as to impart rearward movement thereto.

The equipment may also comprise a harness worn by the pilot and having a yoke extending around the nape of his neck and over those parts of his shoulders adjacent the neck and means for imparting sideways movement is connected to said parts of the harness.

In an alternative arrangement said power means may comprise a source of fluid pressure and said actuating members comprise inflatable pads associated with said equipment and the back and seat of the chair.

In such an arrangement the equipment may comprise a similar yoke to that described above which embraces the neck and shoulders of the occupant and is connected by straps to the chair and to a belt which is connected to the chair and encircles the waist of the occupant which yoke and centre of the belt are provided with inflatable pads and wherein a distributor valve is arranged differentially to place said pads into and out of communication with said source of pressure with or without means for placing them into communication with a source of vacuum.

The belt may be provided with inflatable pads at locations opposite the sides of the occupant.

The aforesaid inflatable pads may be selectively connected to said fluid pressure through selector valve mechanism and said equipment may comprise an auxiliary harness or suit having said pads secured thereto opposite the seat and back of the chair and over the shoulders and opposite the stomach with or without pads over the pilot's sides and a conventional harness is worn over the suit and has straps which are connected to the chair and pass over the shoulders and are connected to the front of a belt also secured to the chair.

In yet a further form of the equipment comprises a conventional harness and supplementary harness the former of which comprises shoulder straps connected at one end to the chair and passing over the shoulders and connected at the other end to the centre of a flexible belt which is also connected to the chair and the supplementary harness comprises a comparatively rigid belt connected to power means adapted to move it in an up and down, fore and aft, or in sideways directions or in any combination of these movements according to the inertia effects on the pilot's body which require to be simulated.

For example, in the above arrangement should the pilot manipulate the controls in a manner which would result in practice in an increased forward velocity, the body of the pilot is pressed back by the power means against his chair to impose the correct pressure on his back and conversely should he operate the controls to effect a decreased forward velocity the body of the pilot is pressed forward by the power means against his harness to impose the correct pressure of the harness on the front of his body.

Again should the pilot manipulate the controls to give an increased vertical velocity the body of the pilot is pressed downwards by the power means into his chair to impose the correct increase in his apparent weight and vice versa. Other changes of pressure upon the pilot's body against his chair and/or harness while seated at the controls of the simulator may be applied according to

any desired combination of adjustments of the controls and instruments which would impose changes of momentum upon the body of the pilot should such adjustments of the controls have been made in actual flight.

As indicated above it is known that the human body is most sensitive to changes of momentum in the abdominal region and for that reason movement is imparted by said power means to the aforesaid auxiliary belt surrounding the pilot. The extent of the movement required is small being limited to the narrow tolerance for movement provided by the pilot's chair and flying harness and thus according to one feature of this invention a movable part of the power means comprises a movable arm passing through an aperture in the back of the pilot's chair and attached to a rigid or semi-rigid portion or portions of the said abdominal belt. The said belt may be composed partly or wholly of flexible, elastic or rigid material and in order to conform with the contours of the pilot's back and abdomen may be provided with an inflatable pneumatic inner membrane. The said belt may be extended to support other areas of the body so that the pressure applied by the said controlling means is distributed as required.

Various supplementary parts of the equipment may be connected to the belt as described and claimed later.

In yet a further form of the invention the equipment is connected to the chair or to the support and said chair is movable in relation to the support in an up and down, fore and aft and sideways direction and power means and associated transmission are provided for imparting any of said movements or combinations thereof.

The following is a description of a number of alternative forms of equipment according to the invention reference being made to the accompanying drawings in which:

FIGURE 1 is a diagrammatic perspective view of a simulator operated by cables;

FIGURE 2 shows a modification of a harness which may be used with the equipment shown in FIGURE 1;

FIGURE 3 shows the harness of FIGURE 2 in use and with an additional head rest and with alternative means for applying pressure to the back, seat and sides of the chair and cable means for applying sideways movement to the neck yoke and shoulder straps;

FIGURE 4 is a diagrammatic perspective view of an alternative simulator operated pneumatically;

FIGURE 5 is a diagrammatic side view of an alternative form of pneumatic simulator embodying an auxiliary harness;

FIGURE 6 is a diagrammatic side view of a mechanically operated simulator;

FIGURE 7 is a perspective side view of the belt without its lining and forming a part of the harness of FIGURE 6;

FIGURE 8 is a diagrammatic perspective exploded view showing more in detail the harness and associated parts of FIGURE 6;

FIGURE 9 is a perspective view of a mechanically tensioned harness and attachments; and

FIGURE 10 is a diagrammatic side view of an alternative form of simulator operated by movement of the pilot's chair.

Like reference numerals refer to like parts in the various figures of the drawing.

The arrangements shown in FIGURES 1, 2 and 3 achieve certain of the objects of the invention in a simple and economic way without substantially changing the normal type of pilot's chair and Sutton type flying harness to which the pilot is accustomed in flight and thus simulation is psychologically assisted in this respect, although not achieving the almost entire bodily movement provided by the means described in FIGURES 6, 7 and 8.

Referring to FIGURES 1, 2 and 3 the two shoulder straps **10** and **11** and the two belt straps **12**, **13** of the normal Sutton or other flying harness are detached at one end from the chair **14** and are connected to cables **15**, **16**, **17**, **18** respectively which are actuated by power means having differentially movable actuating members indicated generally at **9**. A fifth cable **19** passes between the pilot's knees and is attached, to the central plate fastening **20** which connects the straps **10**, **11**, **12** and **13** together. This latter cable **19** when tensioned in conjunction with the cables **15** and **16** tends to equalise the downward pressure on the two shoulder straps **10** and **11**.

The cable **19** is provided with a snap hook **21** for ready detachment of the plate fastening **20** and is helpful in preventing the webbing straps from sliding backwards over the pilot's shoulders. The chair seat **22** and back **23** are provided with movable plates **24**, **25** which may be substantially rectangular. The backplate **25** is hinged at its lower end **8** to swing forwardly about a horizontal axis against the action of a spring **7** and is controlled by a further cable **6** and lever mechanism **5**.

The seat is fixed to a push rod **26**, actuated by cables **4**.

The plates **24**, **25** are padded and arranged so as to permit a total movement of the pilot's body of say 3 to 6 inches from normal.

The positive movement under power by the plates and harness shown particularly assist in providing for the required movement of the pilot's body and may be further used for simulating the type of sudden shock occasioned by air pocket buffeting of an aircraft at high speed or for simulating so-called bumps of any kind.

In order to provide a sideways movement in addition to the vertical up and down movement of the pilot's body the movable plate **24** of the chair seat **22** of FIGURE 1 may be arranged to be separated into three parts **24*a***, **24*b***, **24*c*** as shown in FIGURE 3. The centre part **24*b*** is substantially flat and horizontal and is fixed to a vertical push rod **26** and the parts **24*a*** and **24*c*** are inclined upwardly and sideways in relation to the side edges of the part **24*b*** and fixed to push rods **26*a*** and **26*c*** at right angles to them so that when either of them is pushed upwardly it pushes sideways the pilot's body tending to tilt him about a fore and aft axis. Similarly the back may be formed in three separate parts **25*a***, **25*b***, **25*c***. The centre part **25*b*** is hinged to a push rod so that it may swing about a horizontal axis high up on the back of the pilot and so as to have about a third of the plate above said axis and about two thirds below the axis, whereas the other parts **25*a*** and **25*c*** are inclined to the part **25*b*** and are fixed to push rods **27*a*** and **27*c*** which diverge outwardly from the push rod **27*b*** as they extend rearwardly whereby actuation of either of the rods **25*a***, **25*c*** imparts sideways movement to the pilot's body tending to move him in part about a fore and aft axis, and in part about an upright axis.

To further assist in simulating these movements the cables **17** and **18** may be arranged to be separately and differentially tensioned and relaxed so that the harness tends to be drawn across the pilot's body in either direction thus causing his body to roll to either side of his seat.

The downward pressure of the Sutton shoulder straps **11** when tensioned may be considerable and thus tend to slip outwardly on to the other part of the pilot's shoulders whereafter further tension tends merely to deflect the movable parts of the pilot's collar bones. To prevent this effect the straps **10** and **11** are arranged to pass over a neck yoke **29** shaped from light alloy sheet of the type shown in FIGURE 3, but omitted from FIGURE 1.

The said straps **10** and **11** may slide through guide means **30** FIGURE 2 which permit movement in a fore and aft direction but prevent lateral movement with respect of the edges of the yoke in the region of the neck and the said guide means may be formed from springy material so as to render the yoke readily detachable. In this way the downward tensioning of the straps **10** and **11** will operate through the said yoke **29** to apply pressure over an area around the shoulders in the region of the spine.

Alternative or additional means for securing a lateral or sideways movement of the pilot's body comprise two cables 31, 32 attached by snap hooks to a lug 33 at the back of the yoke shown in FIGURES 2 and 3 and may be alternately tensioned or relaxed laterally to provide the said sideways or laterally rolling movement of the pilot's body. The pilot's helmet 34 (FIGURE 3) may be linked to the yoke by tension springs 35 referred to later.

In order to provide a suitable area of pressure in the neighborhood of the abdomen when the straps 12, 13 are tensioned the fixed side of the fastening means 20 for the normal Sutton flying harness may have attached to it a suitably shaped rigid or semi-rigid back plate 36 FIGURES 1, 2 and 3 extending over the abdomen and lower chest which back plate may be resiliently or inflatably lined.

It will be appreciated that in operating the mechanism shown in FIGURES 1, 2 and 3 to simulate the movements and pressures applied to a pilot due to changes of momentum in flight, the appropriate movable parts of the chair and harness as described above may be employed to apply to the pilot the required movement and pressure in the direction appropriate for the movement of the pilot's controls. The movable parts of the said chair and harness may be arranged to yield somewhat as they would under the same circumstances in flight to take up the slack or spring in the normal fixed Sutton harness and Martin Baker chair and the resilience of the pilot's clothing.

To impose a forward movement of the pilot's head the said back plate 25 may have attached to it a vertical extension 37 (FIGURE 3) which is secured to the normal head rest 38, say of the Martin Baker chair, so that the said head-rest will move with the said back plate and thus ensure that the said head-rest will control the forward movement of the pilot's head.

Other movements of the pilot's head may be secured by cable means or the springs 35 attached to his flying helmet and neck yoke 29 and/or to his oxygen mask (not shown).

A backwards movement of the pilot's head may be effected by tensioning cables 39, 40 detachably fixed to the back or sides of his helmet and passing on either side of the said head-rest.

A known type of centrifugal clutch and spring return 41, 42 already employed in aircraft for controlling the pilot's shoulder straps may be incorporated in the said cable or cables 39, 40 to enable the pilot to make the normal forward movements of his head without undue restraint but to resist and control such movement above a predetermined velocity, for example, that resulting from a force of the order of 1g or more.

The various cables and push rods both in the arrangement of FIGURES 1 and 3 may pass into a control box 9 containing various motors for imparting movement to them which motors may be differentially controlled by potentiometer and/or computer mechanism indicated at 124 and 120 in FIGURE 3 which is conditioned by movement of the pilot's controls such as the joy stick 121, engine throttle controls 122 and manipulating member 123 on the instrument panel 124 incorporating potentiometer controls and controls for an automatic pilot.

FIGURE 4 illustrates simple pneumatic (or hydraulic) means for applying similar movements and pressures to the pilot to those provided by the arrangement illustrated and described for FIGURES 1, 2 and 3.

The normal Sutton type flying harness is provided with a comparatively wide inflatable abdominal pad 43, which pad is disposed in the region of the normal central fastening 20 for the four Sutton harness straps 10, 11, 12, 13 and attached to the fixed fastening side only. The back 23 and seat 22 are provided with inflatable cushions 44, 45 respectively. When the abdominal pad 43 is expanded it presses the pilot backwards against the then

collapsed cushion 45 on the back 23 of his chair. The straps 12, 13 are also provided with inflatable pads 46, 47 and likewise to the shoulder straps 10 and 11 if they are employed in a similar manner to that shown in FIGURE 1 alternatively to a neck yoke 29 as shown in FIGURE 2 and FIGURE 4 which parts may be provided with inflatable pads. This arrangement enables the body of the pilot to be moved in relation to his controls to the position it would occupy in flight. Provided, therefore, that the flying harness is loose when not inflated and the expansion, when operated, considerable and fairly rapid the simulation is reasonably economic and effective. For example, downward pressure in a tight turn would be achieved by suitably collapsing the inflatable seat cushion 44 below the central position and inflating the yoke lining 48 or the pads in the shoulder straps 10 and 11 FIGURE 1.

To simulate an upward pressure as in inverted flying the pressure in the pads of the shoulder straps or in the lining 48 of the yoke 29 would be reduced and the seat cushion 44 would be rapidly inflated, throwing the pilot upwards against his shoulder straps, this movement may be several inches and the pressure if sustained between the inflated seat cushion 44 and deflated straps or yoke would result in the pilot being held high out of his seat in the position he would occupy in inverted flight or in response to a violent downward "bump."

Side thrust on the pilot may, if required, be produced by inflating the pads 46, 47 on the side straps 12, 13.

The same applies to the fore and aft movements occasioned by acceleration and deceleration where the pads 43 and 45 are alternately inflated and deflated.

In all the forms of this invention where movement is applied to the pilot by the inflation or deflation of the pads on the harness and chair any fluid may be employed, for example water. For example, where air is employed the air pressure supply would be arranged to be very rapid through large bore pipes 49, 50, 51, 52, connecting a high pressure cylinder 53 to the pads 48, 45, 44, 43 preferably through an intermediate pressure regulating device 54 having a control 55 and through a quickly opening and closing multi-way selector valve mechanism 56 having a control 57 which determines the degree of pressure required to simulate a particular flight condition and also determines which of the pads are to be inflated or deflated. Deflation of the pads if insufficiently rapid may be assisted by vacuum means connected to a multi-way release valve mechanism 58.

As indicated above the straps 12 and 13 may be fitted with inflatable pads 46, 47 which may be differentially controlled by other pipe lines (not shown) leading to the valves 56, 58 should side pressure effects be required. The controls 55, 57 may be actuated under the influence of the pilot's controls and instruments or as analysed by a computer or by pre-set time control mechanism or directly by the pilot or instructor. The pilot's movement may be arranged to be say 3 inches to 6 inches from his normal central position in relation to his controls.

The tensioned straps of FIGURE 3 may be combined with the inflatable chair seat 44 and chair back 45 of FIGURE 4.

In the arrangement shown in FIGURE 5 the normal chair and flying harness are employed but the pilot is equipped with a specially constructed auxiliary harness or suit externally not dissimilar to the normal pressure suit or pressure jerkin employed for high altitude flying, in fact, for simulator training this special suit may be worn as a substitute for the normal pressure suit or pressure jerkin.

The specially constructed suit is, however, provided at different locations with inflatable portions indicated at 59, 60, 61, 62, and 64. The pads 59 are located in the region of the neck and the parts of the shoulders nearer the neck.

The pad 60 extends over the abdomen and lower parts of the chest.

The pads 61 extend over the pilot's sides beneath the arms.

The pad 62 extends across the back.

The pad 64 extends over the area of the seat.

Thus by differentially controlling the pressure in these portions through pipe lines 5 by valve mechanisms 56, 58 associated with sources of pressure and vacuum in a similar manner to that described with reference to FIGURE 4 the pilot is moved from his normal central position in relation to his controls within the limits of his chair and normal ying harness, and held against the said chair and harness at the required pressure for the required period.

There may be formed over the expandible portions of the said suit loose concertina sided pockets of rubberised fabric, or pockets formed from other expandible or elastic material so as to control the extent and direction of inflation.

The reaction to resist lateral side-thrust from the inflatable pads 61 may be obtained against the side arms of the normal Martin Baker chair but when this type of pilot's chair is not employed the arms of the chair or equivalent members installed for this purpose may fulfill this function.

In order to assist the deflation of the inflated pockets, vacuum means may be incorporated in or operated with the pressure selector-valve and associated pressure controls as shown and described in FIGURE 4.

The arrangement shown in FIGURE 5 may be employed in combination with any of the alternative methods comprised in this invention and is particularly applicable to operational combat aircraft simulators. Where a pressure suit or jerkin is normally worn by the pilot its substitution by an externally similar garment of the type described in FIGURE 5 will not detract from the simulation and procedure of normal flying training.

In FIGURE 6 is shown a form of this invention employing an auxiliary harness which most closely simulates the independent movement of the pilot's body as a whole within the restraining limits of his normal chair and flying harness as is occasioned by the changes of momentum occurring in flight and particularly the feeling of weightlessness such as is experienced in manned space flight but which, however, involves the use of an auxiliary harness as illustrated in addition to the normal flying harness when employed in aircraft (not shown) which is preferably worn within the auxiliary harness.

The pilot's body is mechanically or preferably pneumatically gripped around the abdomen within a substantially rigid belt 65 capable of universal movement, and other parts of his body and equipment may be similarly gripped and moved by means of extensions connected to the said rigid belt as shown in FIGURES 7, 8 and 9. The belt is provided with a pneumatic lining 66 FIGURE 7 and simulation of violent changes of momentum may be physically assisted by the sudden inflation from a source of pressure 67 controlled by a valve 68 and movement of the belt by mechanism indicated generally at 69 (FIGURE 6) and attachments. Small changes of momentum are simulated by a corresponding gentle inflation and movement.

Where no changes of momentum are indicated the deflation of the belt and extensions, which may be accelerated by a source of vacuum means 70 and control valve 71, enables the pilot to move freely without being unnecessarily conscious of restraint as the effective circumference of the belt is readily increased on deflation by more than twelve inches.

In this form of the invention, moreover, instead of being to some extent conscious of local pressures when his body is moved in relation to his chair and flying harness the movement of the belt 65 for example in a fore and aft direction when inflated tends initially to exert an equal air pressure around his abdomen and back without undue indication of the direction of the source of pressure and resulting movement until he is restrained by the fixed parts of his chair and harness.

The pilot can control the degree of pressure by means of an adjustable exhausting valve 126 which automatically exhausts when a preset pressure is reached.

The inflatable belt may communicate with an inflatable yoke shown in FIGURE 8 through a suitable conduit 127.

In the arrangement shown in FIGURE 6 a rigid operating arm 70 is moved in any required direction preferably parallel to its axis by mechanical means indicated generally at 69 which may be known hydraulic or servo motor or other means, which rigid operating arm is detachably and rigidly connected at 71 to the belt FIGURE 7. The belt comprises a number of rigid parts 72, 73, 74 formed from steel, aluminium alloy, or plastics of sufficient strength to prevent deflection under load from the arm 70, which parts are hinged together at 75, 76. The free ends of the parts 73, 74 may be secured together by straps 96 and buckles 97 whereby the belt may be adjusted circumferentially. The rigid or hooped portion may be only of the order of two to six inches wide or sufficient to avoid undue deflection of the belt when the arm 70 is moved.

As shown in FIGURE 6 a chair 14 is rigidly mounted in relation to the mechanical means 69 within the simulator cockpit (not shown) and is provided with an aperture 78 in the back 23 for entry of the said rigid operating arm 70 to enable the said belt 65 and with it the pilot to be moved in any required direction and at the required velocity and pressure within the limits of the said chair 14 and of the normal "Sutton" type or other fixed flying harness indicated at 10 and 12 and connected to the chair in a conventional manner such as is shown in FIGURE 5 the said belt being worn preferably over the harness.

A neck yoke 29 similar to that of FIGURE 2 may be rigidly connected to the belt by the straps 79, 80, 81 82 and buckle attachments 94 on the belt. A boatswain's chair 83 may be connected to the underside of the belt by straps 84, 85 and buckle attachments *94a*. The belt may be interconnected with the pilot's equipment such as his flying helmet and oxygen mask so that when the belt is moved for example to stimulate a dive or a rapid climb the mask moves on the pilot's head. The small relative movement of the belt on the pilot's body facilitated when it is lined with resilient or inflatable pneumatic padding.

The mechanical means for imparting bodily movement to the belt as shown in FIGURE 6 comprises an arrangement of lead screws 88, 89, 90 providing for fore and aft, up and down and sideways movements respectively, which lead screws are fixed against rotation and are engaged by nuts 91, 92, 93 which are rotated by separate motors which may be automatically controlled by movement of the pilot's controls or as analysed by a computer or by pre-set time controlled mechanism or directly by the pilot or the instructor.

A suitable form of rigid expandible belt for the above arrangement comprises sheet steel of ⅛ inch thickness, having a back plate 72 five inches wide by four and a half inches high hinged at 75, 76 to two curved side plates 73, 74, four and a half inches high at the hinged end diminishing uniformly to three inches at the front opening.

The curved side plates 73, 74 have each an arc eighteen inches long and the front edges are adjustably joined by an upper and lower one inch wide webbing straps 96 and buckles 97 attached respectively to the said side plates which may be so arranged as to encompass or tolerate the central fastening of the type of Sutton harness recently adapted to secure both the pilot's parachute harness and

his fixed harness. This harness may thus be worn inside the said rigid belt which is placed around the pilot after completion of his normal routine harness procedure and thus does not interrupt his training in this respect.

In order to obviate undue local pressure of the said comparatively wide belt upon the pilot's body the said belt may be resiliently padded or inflatably lined as indicated at 99 FIGURE 8.

The said padding or inflatable lining may extend above and below the upper and lower edges of the rigid belt and also beyond the open curved frontal edges to form a backing to his said frontal fastenings and to provide a resilient overlap for adjustment of the circumference of the belt.

The said padding or inflatable lining as so extended may be supported by a backing of plastics or other flexible material capable of conforming to the varying curvature of the hinged rigid belt and of supporting the pressure between the pilot's body and the said backing.

When inflatably lined the inflation pressure commonly necessary to grip the body of the pilot is of the order of ½ lb. per sq. inch and seldom exceeds 3 lbs. per sq. inch and thus the said backing need only be of moderate strength and section and thus may provide a convenient anchorage for the attachment of the said padding and of the said inflatable lining.

The said rigid belt 65, neck yoke 29, and boatswain's chair 83 and other attachments of the said belt may be yieldingly lined with foam rubber or the like and may be adjusted by the pilot sufficiently to grip and embrace his body by the adjustable straps and fastenings shown in FIGURES 7 and 8. Alternatively these parts may be provided with inflatable pads.

The said belt may be mechanically tensioned or extended to grip and release the pilot's body to the required degree, for example, by two sheathed cables as shown in FIGURE 9 in which the end of one cable 125 is secured to the front end of the part 73 of the belt and extends across the gap between the parts 73, 74 when it enters its sheath 126a hich extends around the parts 74 and and 72. The other cable 127a is secured to the front end of the part 74 of the belt and extends across between the belt parts 74, 73 when it enters its sheath 128 which extends around the belt parts 73, 72. The cables 125 and 127a leave their sheaves at the back of the belt part 72 and are joined to a single cable 129 which passes into a sheath 130 and thence to the mechanism 69 which imparts movement to the arm 70 and is operated by a separate motor.

The unhinged frontal edges of the curved side plates 73 and 74 when drawn together or released may be arranged to slide over a frontal overlap of the flexible backing for the belt as described and may thus be free to move out of contact with the pilot's clothing or harness.

The said hinges 75, 76 of the said belt may be provided with opening springs 100 so that the circumference of the belt tends to increase.

Thus in simulated steady flight where no change of momentum is occasioned the said belt may be mechanically extended or enlarged so that the grip on the pilot is relaxed and he is free to move in relation to his chair. Where, however, a change of momentum is arranged to occur in response to movement of the engine or flight controls by the pilot or by pre-set time mechanism or by the instructor the said belt is mechanically tensioned to grip the pilot's body so that he may be firmly moved in response to the movements of the said operating arm 70 and rigid belt in response to indicated changes of momentum.

Similar means may be employed to tension or release the said yoke 29, boatswain's chair straps 84, 85.

It will be appreciated that the inflatable linings instead of being attached to the rigid belt, collar and boatswain's chair as in FIGURE 8 may take the form of a separate inflatable harness or garment attached to the pilot somewhat similarly to that shown in FIGURE 5. In this case before entering the said rigid belt 65 and associated collar 29 the pilot may have attached to him a wholly or partly inflatable harness which may take the form of a waistcoat or suit of rubberised fabric which may be inflated after he has entered the said rigid belt and associated parts so that his body may be gripped within it at the required pressure. A conventional harness such as is shown in FIGURE 5 is preferably worn under said inflatable garment in order that when the pilot is moved by the said belt the normal harness may press directly against the pilot's body in the usual way. The said conventional harness may be worn outside said inflatable garment in order to follow the normal practice although the pressure of the conventional harness on the pilot's body is somewhat reduced. Alternatively the pilot's pressure suit or pressure jerkin, if normally worn for simulator training, may readily be converted and employed for this purpose by connecting it, or separate compartments formed in it, by piping through selector valve mechanism to a source of pressure and vacuum as previously described.

In order to facilitate the attachment of the said inflatable linings to said rigid belt and associated harness and to provide for their extension over a wider area than that provided by the rigid belt as shown in FIGURE 8 the said rigid belt 65, collar 29 and boatswain's chair 83 may be first lined with an inner backing of plastics sheet, leather or the like which inner backing may extend beyond the edges of the said parts to provide a greater area for the application of pneumatic pressure and to form a convenient attachment to the said inflatable inner membrane or lining and to permit some small movement of the attached edges of the said inflatable membrane when inflated or evacuated.

The said inner membrane is preferably composed or rubberised fabric but may be of plastics, or of any elastic inflatable material for example rubber and may be provided with a pneumatic pressure control or safety valve 126 situated for example on the upper front edge of the said inflatable lining 99 as shown in FIGURE 8 or to any convenient part of it if worn as a garment. The belt may be connected through a conduit 101 and valves 68 or 71 to a source 67 of supply of high pressure air for example a compressed air cylinder or with a source of vacuum 77. The said source of high pressure air may also communicate with the inflatable membranes of the said yoke 29, or of the boatswain's chair which may for example communicate by flexible tubing with the inner membrane of the said rigid belt.

The pneumatic pressure applied to the pilot's body through the aforementioned harness in the manner described may be adjusted by the pilot by means of the pressure controlling safety valve 126 to suit his own comfort and sufficiently to provide an even pressure to insulate him from the rigid parts and semi-rigid parts of the said harness when inflated. Where required for the comfort of the pilot it may be arranged for the pneumatic pressure to be released during periods of simulated steady flight involving no substantial changes of momentum the said pressure being automatically and rapidly restored to the required level should changes of momentum occur which would result in substantial movement of the said rigid belt and attached harness. This may be achieved by connecting the said high pressure air supply through a known type of pressure reducing valve set to the required pressure limit the said high pressure air being injected or released by means responsive to changes in velocity as described in FIGURE 4. This will enable the pilot to have free movement within the said belt and harness to operate his controls in the normal way unless otherwise required to be controlled by changes of momentum.

The automatic change in pressure may be obtained by movement of certain of the pilot's controls for example his throttle and elevator controls by adjustment of his

instruments or again by a pre-set time control mechanism or by the instructor.

In the arrangement shown in FIGURES 6 to 8 where in order to simulate a change of momentum in which the pilot must be forcibly lifted upwards from his seat and subjected to great upward pressure against the shoulder straps of his normal flying harness and the simulation for this purpose provided by the said boatswain's chair or thigh straps and the circumferential grip of the said rigid belt may not provide sufficient bodily upward lift of the pilot, the upper edge of the said rigid belt may as shown in FIGURE 9 be provided with two rigid vertical crutch-like attachments **102** to extend upwards below each armpit the rigid curved upper portion of the said crutch being provided with upper resilient or inflatable padding **103** to conform to the contours of the pilot's lower arm and armpit.

Each crutch **102** may be adjustable in an up and down direction for which purpose the shank portion **104** may be slotted at **104a** and passed over a stud on the belt which is provided with a clamping nut **105**.

The support for the pilot's thighs in the neighbourhood of the spine may be provided as already described by a transverse plate **83** similar to the seat of a boatswain's chair being arranged to pass under the pilot and be adjustably attached at both ends to the lower edges of the belt.

It has been found by experiment that a sensation of almost complete levitation or weightlessness may be imparted to a seated individual if he is lifted by an even pressure applied upwards below the armpits and beneath the thighs in the region of the lower spine and this effect is obtained by applying upward movement of the rigid belt associated with movement of the said boatswain's chair either alone or in combination with the said underarm supports.

Similarly it has been found that a downward pressure of the body on to the pilot's seat of an aircraft during a loop or tight turn is most closely simulated by applying a downward pressure at the back and sides of the neck and inner shoulders in the region of the spine accompanied by a circumferential downward pressure in the region of the abdomen and this effect is obtained by applying downward movement to the belt which is linked to the collar **29**.

It is considered desirable in operating conventional flight simulators to endeavour to introduce a feeling of tension or even apprehension in the mind of a pilot when engaged in simulated combat or other critical manoeuvres, and this feeling may be assisted when a violent change of momentum is indicated by suddenly inflating the said harness FIGURES 6 to 8 to grip the pilot and then by applying the required vigorous movement and force upon his body in relation to his chair and flying harness. This feature associated with the method described in FIGURES 6 to 8 may be found particularly advantageous in simulating the "catapult" take-off and "arrestor hook" landing employed in aircraft carriers where sudden forces of the order of 4G are encountered.

In the arrangement shown in FIGURE 10 instead of the pilot being moved relatively to the chair **14** and harness as in the previous constructions, bodily movement is imparted to the chair itself.

The chair may be provided with a substantially rectangular frame and at or near each corner of the frame there is mounted a jack cylinder **107** within which is mounted a piston or ram **108**. The lower end of the piston rod of each ram has fixed to it a castor wheel **109** which runs on a flat surface. Also attached to the chair frame are four cables **110**, **111**, **112**, and **113** which are actuated by four independent motors (not shown) so that the resulting force from the pull of the cables may move the chair frame in any direction in the horizontal plane, whereas the differential operation of the jacks **107** may tilt the chair in various directions or may move it bodily in an up and down direction.

The pilot may be held in the chair by conventional harness straps **10**, **11**, **12**, **13** which may be affixed thereto but instead of these straps being connected to the chair they may be anchored to the floor by cables **115**, **116**, **117**, **118** and the releasable clamp **20** is connected to the floor by a cable **119**.

Alternatively the chair may be rigidly fixed against horizontal movement and thus the cables **110**, **111**, **112**, and **113** are eliminated but the jacks are retained so as to impart tilt at various angles and/or up and down movement. Thus the effects of changes of momentum and particularly of "bumps" or the "buffeting" of an aircraft may be economically simulated, and the apparatus may conveniently be applied to commercial passenger-aircraft simulators. As indicated above the normal flying harness may be attached to the chair but if sustained restraining pressure is required to be simulated the ends of the harness normally attached to the chair may be attached to the floor of the simulator as shown in FIGURE 10.

The selective control of the power means for obtaining the movement and pressure applied to the pilot according to this invention may be by linkage by known means to the pilot's controls and instruments by potentiometer means and or as analysed by a computer or by time control or by manual means operated by the instructor or pupil.

A simple known means of simulating, for example, the readings of the pilot's instruments is by electrical or other linkage with the pilot's engine and flying controls and this means is also employed for adjusting the attitude of the simulator as a whole, for applying total movements of a few feet to the simulator, and for regulating the resistance of the pilot's flying controls in relation to the supposed or indicated speed of the simulator.

These or similar automatic means may be employed for selecting and regulating the movement to be applied in the manner described to the pilot's body by the various means provided by this invention, and this existing mechanism provides a convenient way of adapting this invention for use in existing flight simulators.

Where however no such mechanism already exists for automatically controlling the power means employed in this invention, a simple automatic selection control of the power means may be provided by electrical linkage with the pilot's operating controls employing known potentiometer, computer and servo motor technique.

For example the pilot is pressed back in his seat as the result of acceleration in proportion to a pre-calculated function of the rate and extent of the throttle opening, the pressure being relieved after a pre-calculated period. A reverse pressure is applied when the throttle is closed, the flaps operated and the landing brakes applied according to the extent and rate of application of these controls and the resultant pre-calculated deceleration. Similarly according to the rate and extent of the throttle opening and the estimated change of angular velocity of the aircraft as indicated by the movement of the elevator controls the pilot is pressed downward into his seat or lifted from it. Sideways thrust is similarly applied to the pilot where the rudder controls are operated in flight in relation to a given throttle position without use of aileron or elevator controls.

Hitherto in flight simulators effective means have been provided for simulating the visual and aural environment of a pilot and for providing him with practice in cockpit and navigational procedure and with small short-period movement and vibration.

Such means may be retained in the present arrangement and according to this invention, relatively simple means are further provided for simulating the physical reaction, movement and sustained pressure within his chair and harness suffered by a pilot in actual flight which

movement and pressure, particularly during combat manoeuvres, involve pressures of many times his own weight over a prolonged period of time.

It will be appreciated that any of the forms of the invention as described in FIGURES 1 to 10 and otherwise comprising this invention may be used to supplement or provide additional movements and pressures to those provided by conventional flight simulators where the cockpit itself is moved to an insufficient extent to provide movement and sustained pressures.

I claim:

1. An apparatus to simulate changes in movement of a vehicle comprising a chair to be occupied by an occupant; harness means on said chair for engaging portions of the body of the occupant of said chair to hold said occupant yieldingly in position; a plurality of different selectively operable means for applying controllable, variable, independent pressures to selected portions of said occupant's body including external mechanical means for applying movement to parts of the chair and harness and said operable means and said harness means permitting a controled and restrained, yielding movement of the occupant's body limited by said harness in the selected direction of the applied pressure relative to the chair whereby inertia forces as would result from changes in movement of said chair are simulated.

2. An apparatus according to claim 1 wherein said harness means includes a yoke containing guideways extending around the nape of the occupant's neck and over those parts of his shoulders adjacent the neck and wherein said selectively operable means is connected to said harness means, said harness means including straps which fit over the shoulders and pass through said guideways in said yoke whereby tension in the straps exerts a downward pressure on said yoke and upon the occupant's spine and which guideways prevent the straps from slipping off the yoke onto the occupant's shoulders.

3. An apparatus according to claim 1 wherein said harness means comprises a conventional harness and a supplementary harness the former of which comprises shoulder straps connected at one end to the chair and passing over the shoulders and connected at the other end to the center of a flexible belt which is also connected to the chair and the supplementary harness comprises a comparatively rigid belt connected to power means which is adapted to move it in an up and down, fore and aft, or in sideways directions or in any combination of these movements according to the inertial effect to be simulated.

4. An apparatus according to claim 3 wherein said comparatively rigid belt has rigidly fixed thereto a shaft which extends through an opening in the back of said chair and is operated by said power means through a transmission arranged to impart to it said combination of movements.

5. An apparatus according to claim 3 wherein a yoke including guideways is arranged to extend over the shoulders and around the neck of said occupant and over or under the conventional harness and is attached by straps to the back and front of the comparatively rigid belt and wherein the shoulder straps of the conventional harness are arranged to extend through said guideways in said yoke.

6. An apparatus according to claim 5 wherein said yoke and belt include inflatable padding.

7. An apparatus according to claim 3 wherein a boatswain's type chair is adjustably attached to opposite sides of the belt.

8. An apparatus according to claim 3 wherein crutches are adjustably mounted on said comparatively rigid belt, so as to be movable in an up and down direction and to be engageable beneath the armpits of the occupant.

9. An apparatus according to claim 3 wherein means are provided for contracting and expanding said comparatively rigid belt.

10. An apparatus for simulating changes in movement of a vehicle comprising a chair frame having a back and a seat and arranged to rest upon a support, a harness having parts which extend over the shoulders of the occupant of the chair and downwardly towards the seat and a part engageable with at least the abdomen of the occupant extending towards the back of the chair, which chair and parts are arranged to locate the body of the occupant in a normal position but permit yield in an up and down and fore and aft direction, and controllable power means adapted to impart controllable pressure and movement to the occupant's body in said directions through at least one of said parts including external mechanical means for applying movement to parts of the chair and harness and said power means and harness permitting a controlled and restrained, yielding movement of the occupant's body limited by said harness in the selected direction of the applied pressure relative to the chair.

11. An apparatus according to claim 10 wherein said seat and parts of the harness which extend across the shoulders of the occupant and downwardly towards said seat are movable in an up and down direction relatively to the chair frame and the back of the chair and said part of harness which engages at least the abdomen of the occupant are movable relatively to the chair frame in a fore and aft direction and said power means is provided with differentially movable actuating means connected to said seat, back and said parts of the harness.

12. An apparatus according to claim 10 wherein said parts of the harness which extend across the shoulders of the occupant and downwardly towards said seat are fixed against up and down movement and said part of the harness which engages at least the abdomen of the occupant is fixed against fore and aft movement and said power means comprises differentially movable actuating means adapted to impart fore and aft movement and up and down movement to said chair.

13. An apparatus according to claim 10 wherein means are provided for imparting movement to auxiliary equipment relative to said occupant.

14. An apparatus according to claim 10 wherein said power means provided with controls linked to computer mechanism by potentiometers and servo motors and is conditioned by vehicle controls actuated by said occupant.

15. An apparatus according to claim 14 wherein said power means is controlled by the potentiometers and servos direct from pilot controls and instruments.

16. An apparatus according to claim 12 wherein those parts of the harness which extend over the shoulders and downwardly towards the seat are connected to the part which engages the abdomen and which part is connected to the support and wherein those parts of the harness which extend downwardly from the shoulders at the back of the occupant are fixed to said support.

17. An apparatus according to claim 11 wherein each of said movable seat and back portions of said chair are formed in a number of parts and said power means is provided with actuating means for differentially moving the said parts so that the occupant may be moved bodily sideways or tilted sideways.

18. An apparatus according to claim 11 wherein a said power means is provided with controls for selectively imparting relative variable movements between the parts of the equipment and parts of the chair, which control means are arranged to be actuated by the occupant in operating his controls.

19. An apparatus according to claim 11 wherein parts of the harness which extend downwardly towards the seat are connected to that part of the harness which engages the abdomen of the occupant, and wherein two other parts of the harness which extend downwardly from the shoulders are connected to independently operated members of said power means.

20. An apparatus according to claim 11 and wherein the part of the harness which engages shoulders of the

occupant has extensions on opposite sides of the occupant which are connected to independently operated members of the power means whereby sideways movement may be imparted to the occupant.

21. Apparatus according to claim **11** for simiulating the changes in movement and attitude of a vehicle comprising a chair frame of the kind normally used for the vehicle, the seat and back of which or parts thereof are adapted to be movable and are connected to members of the power means, and a harness having parts which extend over the shoulders of the occupant and other parts which embrace at least the abdomen of the occupant, and other parts extending on opposite sides of the occupant each of which parts are attached to cables or the like connected to members of the power means so that variable up and down, fore and aft and sideways pressure and movement may be applied to the occupant from the said power means.

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CENTRIFUGAL EXERCISER

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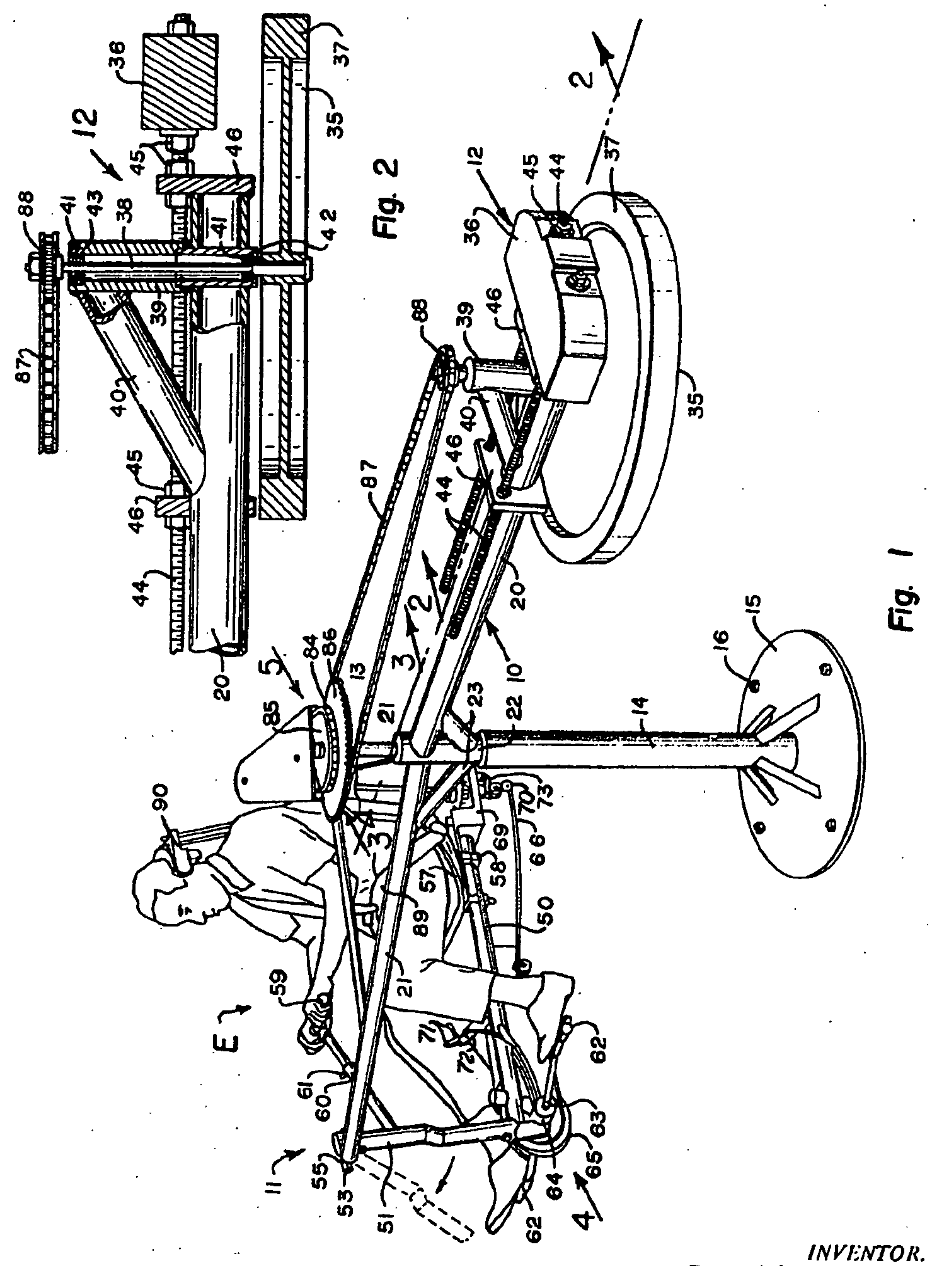

Fig. 2

Fig. 1

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CENTRIFUGAL EXERCISER

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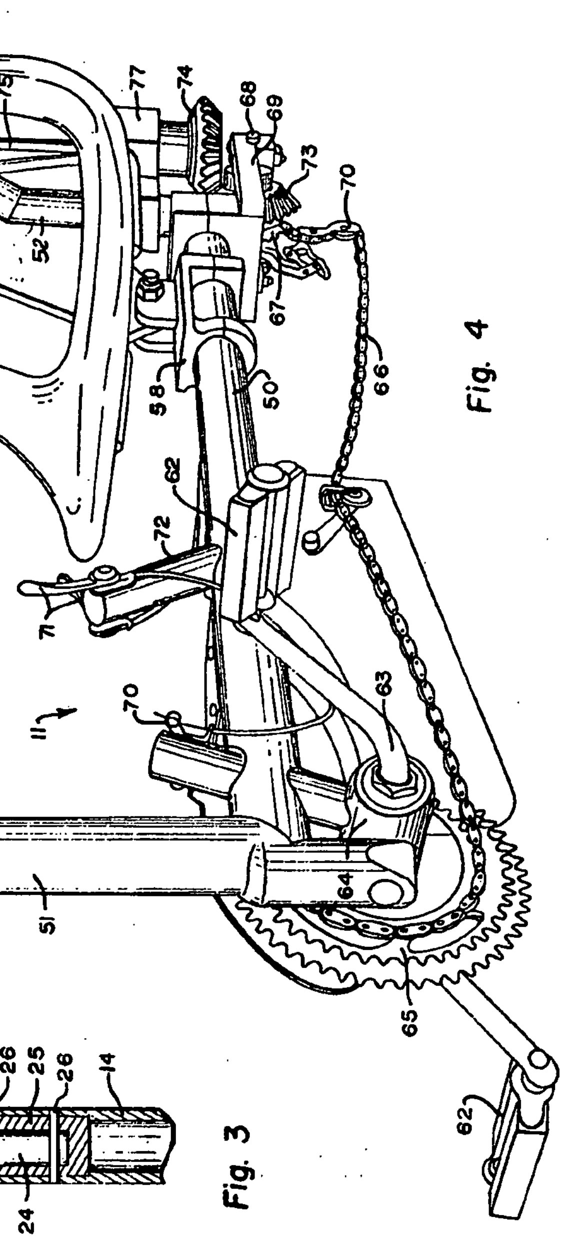

Fig. 4

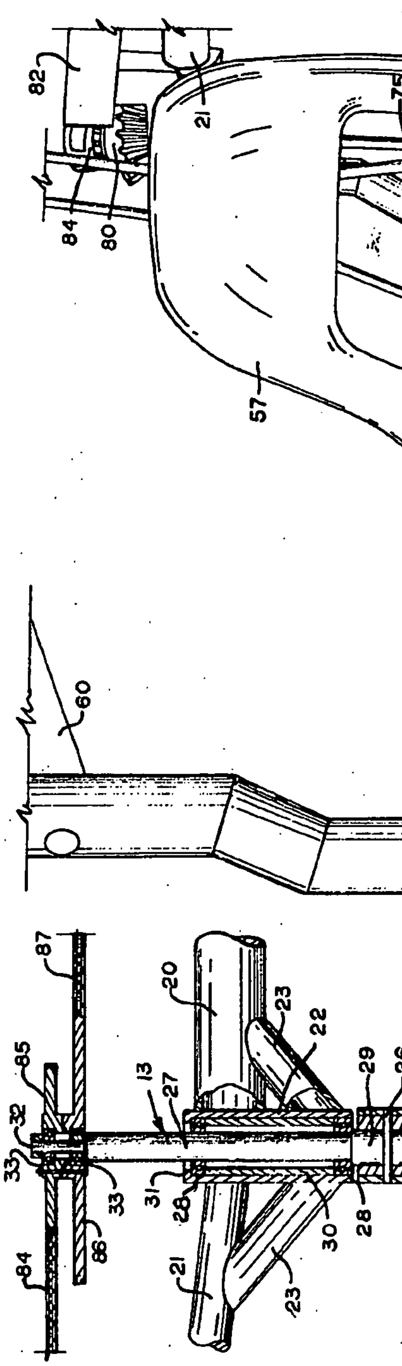

Fig. 3

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CENTRIFUGAL EXERCISER

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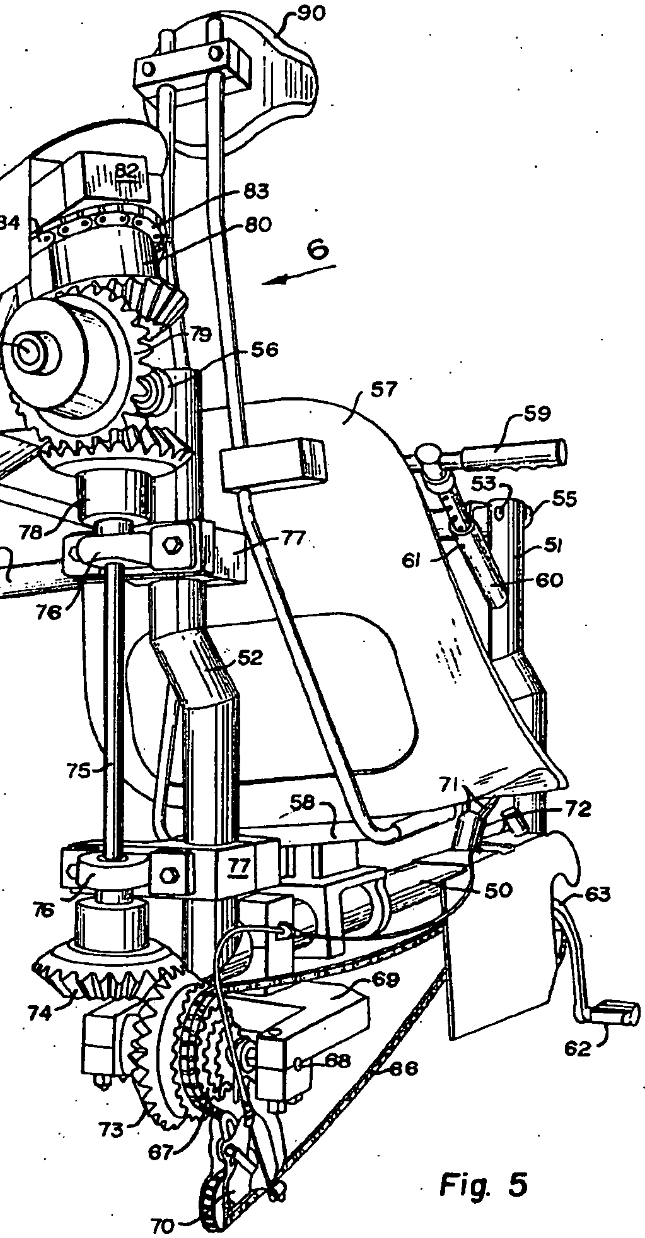

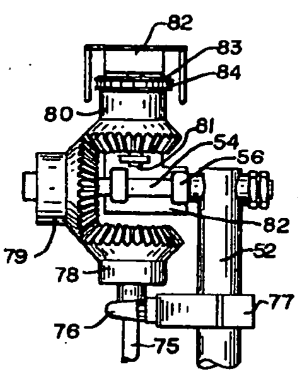

Fig. 6

Fig. 5

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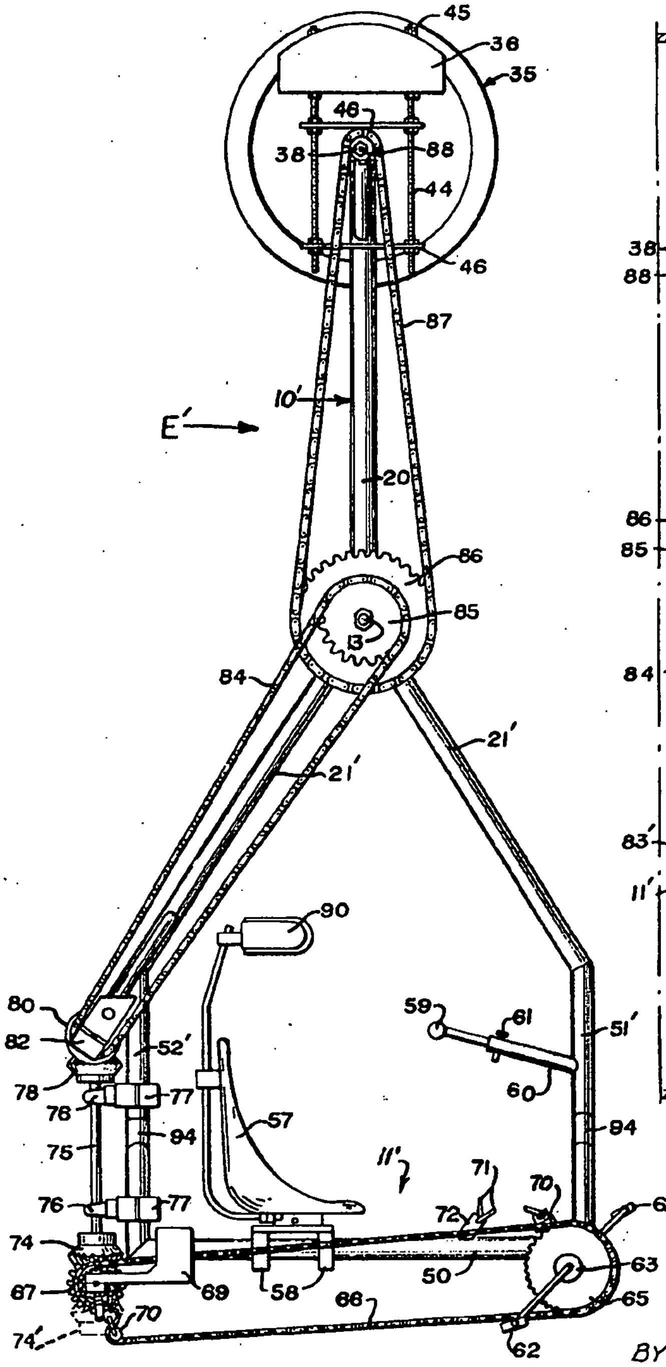

Fig. 7

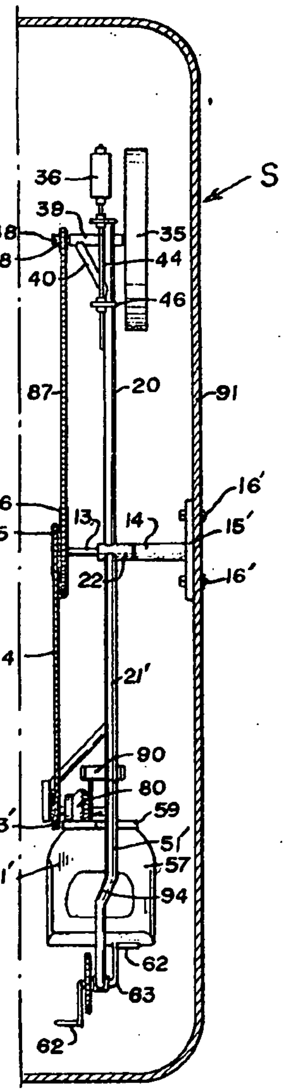

Fig. 8

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CENTRIFUGAL EXERCISER

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U.S. Cl. 272—33 13 Claims

ABSTRACT OF THE DISCLOSURE

The centrifugal apparatus includes an elongated frame which is supported for rotation at its central portion. The frame carries a cradle at one end which is adapted to accommodate a passenger and a counterweight disposed at the opposite end of the frame. The counterweight is adjustable to compensate for different passenger weights. The counterweight includes a rotatable flywheel mounted for rotation about an axis parallel to the axis of rotation of the frame. A manual drive means is provided for rotating the frame and comprises a pedal device located on the cradle and driven by the passenger. The drive is transmitted from the pedals to the rotatable flywheel and drives the flywheel in one direction of rotation which in turn rotates the frame in the opposite direction.

This invention relates to vehicular exercising apparatus and more particularly to rotary vehicular exercisers, which simultaneously supply artifical gravity, wherein a passenger will spin about a circular path.

A primary object of the present invention is to provide a novel construction of a rotary vehicle for use as an exerciser and for spinning a passenger about a circular path with sufficient rapidity to create a substantial centrifugal force upon the passenger's body. As such, the invention will be hereinafter called a "centrifugal exerciser."

It is anticipated that the centrifugal exerciser, the present invention, can be advantageously used in space travel, and accordingly, another object of the invention is to provide a novel and improved centrifugal exerciser which is a self-propelled unit capable of operating in a zero-gravity environment as in a spaceship.

As more extensive trips into outer space are being planned, the physiological effects of prolonged living in a zero-gravity, weightless environment become a matter of concern. For example, it has been observed that an astronaut's rate of heart beat will slow down significantly after a few days in space, but will speed up considerably above normal as he is returning to earth. Another concern is an undesirable loss of muscle tone in a prolonged weightless environment. It is generally conceded that these observed, and other physical changes can bring about severe and even dangerous physical reactions after a prolonged trip into space.

It has been suggested that a space traveler can avoid the deleterious effects which may be produced by weightlessness through periodic and repeated exercises of a type which not only stimulate the individual's physique, but also produces a simulated gravitational effect on his body. The natural and obvious mode of simulating gravity effects is to place an individual at the rim of a whirling apparatus to impose centrifugal forces upon his body during an exercise period. Such centrifugal forces may vary in intensity depending upon the speed of rotation of the apparatus and insofar as the individual is concerned, produce the same effect as if he were on the earth's surface.

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Although the concept of such means for maintaining the physical condition of spacecraft crews is generally accepted, the weight penalty of such apparatus appears at first to be prohibitive, not only because of the weight and bulk of the device itself but, more important, because of the weight of propellants required to cancel out the reaction of the device upon the spacecraft by use of the spacecraft altitude control system.

Accordingly, an object of the invention is to provide a novel and improved centrifugal exerciser which is a compact, lightweight unit, of a carefully balanced construction and which may be easily incorporated into a spaceship design.

Another object of the invention is to provide a novel and improved centrifugal exerciser for a spaceship which is manually operated by a passenger, commencing as from a position at rest, as within a spaceship, easily rotated to the speed which produces a desired centrifugal effect, and thereafter returned to the original resting position.

A further object of the invention is to provide a novel and improved centrifugal exerciser for a spaceship which is a self-contained, well-balanced unit which will not vibrate or wobble on its mounting spindle within the spaceship and which may be accelerated to any desired speed of rotation without imposing torque upon its mounting spindle or on the spaceship.

Another important object of the invention is to provide a novel and improved centrifugal exerciser which may be used in a zero-gravity environment and also may be used in a normal terrestrial gravity environment with slight modifications.

Another object of the invention is to provide a novel and improved centrifugal exerciser which can be built, tested and proven through the construction of a terrestrial unit, to produce a compact, efficient, reliable unit for zero-gravity use.

A further object of the invention is to provide, in a centrifugal exerciser, a unique arrangement of counterweights and balancing members to produce a self-contained, fully-balanced apparatus with a minimum possible overall weight and bulk.

With the foregoing and other objects in view, all of which more fully hereinafter appear, my invention comprises certain constructions, combinations and arrangements of parts and elements as hereinafter described, defined in the appended claims and illustrated in preferred embodiments in the accompanying drawing, in which:

FIGURE 1 is a perspective view of a first embodiment of the centrifugal exerciser, illustrating the same as carrying a passenger and with broken lines at one portion indicating the manner in which the passenger-carrying cradle section swings when the apparatus is in use.

FIGURE 2 is a fragmentary sectional detail of the counterbalancing portion of the apparatus as taken substantially from the indicated line 2—2 at FIG. 1.

FIGURE 3 is a fragmentary sectional detail of the central mounting pivot of the apparatus as taken substantially from the indicated line 3—3 at FIG. 1.

FIGURE 4 is a front perspective view of the passenger-carrying cradle of the apparatus as taken substantially from the indicated arrow 4 at FIG. 1.

FIGURE 5 is a rear perspective view of the passenger-carrying section of the apparatus as taken substantially from the indicated arrow 5 at FIG. 1.

FIGURE 6 is a fragmentary elevational detail view as taken from the indicated arrow 6 at FIG. 5.

FIGURE 7 is a side elevational view of a second embodiment of the centrifugal exerciser, which is especially adapted to be used in a zero-gravity environment.

FIGURE 8 is a reduced-scale, front elevational view of the exerciser illustrated at FIG. 7, wherein the apparatus is illustrated as being mounted within an annular housing as at an end of a spaceship compartment.

The improved centrifugal exerciser was conceived and developed to produce a terrestrial unit which can be easily modified for use in a zero-gravity environment, as in a spaceship. To accomplish this, the terrestrial unit was designed to rotate in a horizontal plane, about a vertical spindle axis, so that gravity forces on the apparatus would be normal to the plane of rotation, and would not produce components in this rotative plane. Accordingly, the balancing-out of gravity forces at each side of the vertical spindle axis produces a condition simulating a zero-gravity environment in the horizontal plane of rotation.

The exerciser is, basically, a longitudinally-extended structure, mounted upon a central vertical spindle. It is adapted to carry a passenger at one side of the spindle and counterweights at the opposite side thereof. The apparatus must be carefully balanced upon this central spindle to avoid vibration and wobbling as it is rotated. Such balancing is of considerable importance since the comparatively light weight of the spaceship, wherein a zero-gravity unit may be used, simply cannot serve as a buttress to take care of irregularities of weight distribution in the apparatus. Also, the frame connection to the spindle must be substantially frictionless to prevent torque from being imparted to the spaceship as the exerciser is rotated. Moreover, the exerciser must be self-contained in that external torque action cannot be used to initiate rotation and to later stop the rotation without disturbing the orientation of the spacecraft.

The physical phenomenon involved in rendering the exerciser a self-contained, self-operating unit involves the application of conservation of momentum and in this instance, the conservation of angular momentum. Accordingly, the invention includes the concept of providing a flywheel adapted to be at rest whenever the exerciser is at rest and to be rotated in one direction to rotate the exerciser in the opposite direction. In order to minimize the overall weight of the apparatus, this flywheel is mounted away from the spindle to serve also as a counterweight. It thus serves a double function, to balance the apparatus, including a passenger, on the central pivot and to create angular momentum to rotate the apparatus. As an exerciser, it is further contemplated that this flywheel will be rotated by efforts of the passenger through suitable drive mechanisms, as will be set forth in detail.

Referring more particularly to the drawing, the terrestrial unit of a centrifugal exerciser E is illustrated at FIGS. 1 to 6. A modified unit E', for a zero-gravity environment, is illustrated at FIGS. 7 and 8, as will be hereinafter further described. The exerciser E is formed as an elongated Y-frame 10 having a passenger-carrying cradle 11 at one end and a counterweight assembly 12 at the other end. The frame 10 is supported upon a central spindle 13 which, in turn, is mounted in a vertical post 14. The post, holding the spindle vertically, is formed with a flange 15 at its base to permit it to be securely anchored to a floor, as by lug bolts 16 extending through suitable holes in the flange and into the floor.

The Y-frame 10 is formed of lightweight, tubular structural members suitably welded together. It includes a leg 20 at one side of the spindle to carry the counterweight assembly 12 and a pair of diverging arms 21 at the other side of the spindle to support the passenger cradle 11. The length of the legs and arms is such as to provide a balance point at the crotch of the Y where the leg and arms come together. The frame includes a short, tubular sleeve 22 at this crotch which is suitably welded to the frame members to depend normally from the plane of the Y-frame and to hold the spindle 13. Reinforcing struts 23 connect the leg 20 and arms 21 with the lower end of the sleeve 22 to enhance the strength and rigidity of the assembly.

As seen in FIG. 3, the spindle 13 is a cylindrical rod which is stepped into sections of decreasing diameter. A base section 24, of maximum diameter, fits into a socketed plug 25 at the top of the post 14. Rivets 26 extending through the top of the post hold these members together. An intermediate spindle section 27 of smaller diameter extends through and above the frame sleeve 22 and supports the frame by a pair of radial-thrust type bearings 28 on the spindle and within the sleeve. A lower bearing sets upon the shoulder 29 between the base and intermediate sections of the spindle and is fitted into the lower end of the sleeve 22. A spacer tube 30 within the sleeve separates the upper and lower bearings 28. The upper bearing is at the top end of the sleeve and abuts against an inturned flange 31 of the sleeve to support the frame 10 upon the spindle 13. An upper section 32 at the top of the spindle, of further reduced diameter, holds a pair of bearings 33 which support idler sprockets, hereinafter described.

The counterweight assembly 12 at the outward end of the leg 20 includes a flywheel 35 and a fixed weight 36. The flywheel serves two functions, first, to impart angular momentum to rotate the apparatus, and secondly, to supplement the fixed weight 36 in balancing the weight of a passenger at the opposite end of the apparatus. Accordingly, the flywheel 35 is a comparatively heavy member with a heavy rim 37. It is mounted to lie in a horizontal plane at the underside of the leg 20 and is carried by a vertical shaft 38 which extends upwardly and through sleeve 39 near the end of the leg. The sleeve 39 is formed of tubular members extending through and upstanding from the leg 20, suitably welded into position on the leg and further secured by a strut 40, as shown at FIG. 2. The shaft 38 is mounted in this sleeve 39 by a pair of bearings 41, one being positioned at the bottom of the sleeve against an inwardly turned flange 42 and the other at the top of the sleeve in a socket 43. The top portion of the shaft 38 extends above the sleeve to carry a drive sprocket, hereinafter described.

The fixed weight 36 is adjustable to shift outwardly and inwardly from the leg 20 so that it may be positioned to balance the apparatus to the different weights of the individuals who may use it. It is mounted upon a pair of threaded rods 44 which lie in spaced parallelism with the leg 20, which each rod being at one side of the leg and extending beyond the outward end of the leg. Each outwardly extended rod portion fits into a hole through the weight and is fastened to the weight by lock nuts 45. The rods are also affixed to the leg 20 by a pair of rectangular brackets 46. Each bracket is transversely mounted on the leg, with one bracket being at the end of the leg and the other being spaced a short distance inwardly from the end thereof. Each bracket includes a pair of holes wherethrough the rods are extended, and the rods are adjustably positioned upon these brackets by opposing lock nuts 45, as in the manner illustrated at FIG. 2.

Where the apparatus is used frequently by many persons and adjustments of the fixed weight 36 are also frequent, it is contemplated that the adjustments may be controlled by a servo mechanism, not shown, by eliminating the nut 45 which connect the rods to the brackets 46 and replacing them with shifting screws affixed to a bracket

and rotated by the servo mechanism. However, a manually adjustable apparatus, such as that illustrated, is preferable for the sake of simplicity where adjustments of this weight will not be excessively frequent.

The passenger cradle 11 is formed as a squat, U-shaped structure having a transversely disposed base tube 50 and a front arm 51 and a rear arm 52 upstanding from the respective ends of the base tube, as clearly seen in FIG. 5. The top ends of the cradle arms lie between and are pivotally connected to the outward ends of a frame arms 21 by a front pivot rod 53 and a rear pivot rod 54 which are secured to the respective arms 51 and 52 and are aligned on a common, transverse axis. These pivot rods are suspended, respectively, in a front bearing 55 and rear bearings 56 at the ends of the frame arms 21.

A passenger seat 57 is mounted upon the base tube 50 of the cradle at a position adjacent to the rear arm 52, the mounting being effected by a clamp head 58 at the underside of the seat. A balancing handle 59 is mounted upon a post 60 which is attached to the front arm 51 to extend rearwardly from that arm and place the handle at a position where a passenger may easily grip it. The post 60 is adjustable in length by providing two telescopically interconnected tubular portions which may be locked together as by a pin 61 extending through suitable registering holes in the post portions. To complete the cradle, a manual driving mechanism is mounted on the base tube 50, the preferred driving mechanism, as illustrated, is a pedal system similar to a bicycle drive, as will be hereinafter further described.

With this arrangement, the cradle 11 is suspended in the horizontally disposed frame 10 to hang vertically therefrom when the apparatus is at rest, but to swing outwardly and away from the frame 10 as it is being rotated, as in the manner indicated by the broken-line portion of the arm 51, illustrated at FIG. 1. The centrifugal force producing this outward swing of the cradle is a horizontal component proportional to the speed of rotation of the apparatus. The gravity force, due to the weight of the passenger and cradle, is a vertical component which remains constant and which is not influenced by, nor influences, the horizontal centrifugal forces. Accordingly, excepting for a small unbalance due to the outward swing of the cradle as it speeds rotation, the horizontal components of forces and momentum effects on the apparatus, which vary according to the speed of rotation of the apparatus, will simulate the action of the apparatus in a zero-gravity environment.

The manual drive includes a train of mechanisms which extend from foot pedals 62 at the lower front end of the cradle to the flywheel 35 at the opposite end of the apparatus, as best seen in FIG. 1. The first section of this train of mechanisms includes the pedals 62 at each side of a pedal shaft 63 which is mounted in a frame bearing 64 secured to the underside of the forward end of the base tube 50. A nest of three drive sprockets 65, of different diameters, is carried on this pedal shaft and a chain 66 is meshed upon one of the sprockets to extend rearwardly to mesh with one of a nest of rear driven sprockets 67, clearly shown in FIG. 4. These rear sprockets 67 are mounted upon a shaft 68 carried in a U-shaped bracket 69 which is clamped to the base tube 50 to extend rearwardly of the rear arm 52 of a cradle, as in FIG. 5. The pedals, driving sprockets 65, chain 66 and driven sprockets 67 are similar to a conventional bicycle drive. To obtain variable speeds of operation, the chain is shifted from one sprocket to another at either the front sprocket nest 65 or the rear sprocket nest by conventional bicycle derailing devices, generally indicated as 70 in FIGS. 4 and 5, which is regulated by controls 71 affixed to suitable spurs 72 upstanding from the base tube 50.

The nest of driven sprockets 67 is connected with a first bevel gear 73, on the shaft 68. This bevel gear meshes with a second bevel gear 74, as best seen in FIG. 5, which is mounted on the end of a shaft 75, perpendicular to the shaft 68 and paralleling the arm 52. This shaft 75 is mounted in bearings 76 secured to the arm 52 by clamp heads 77. A third bevel gear 78 is mounted at the top of the shaft 75 adjacent to the pivot rod 54 which connects the rear arm 52 of the cradle with the frame arm 21. A fourth bevel gear 79, an idler gear, is mounted upon an extension of this rear pivot rod 54 to mesh with the third gear and also mesh with a fifth bevel gear 80 which is mounted upon a shaft 81 carried in a pivot block 82, as in FIG. 6, attached to the end of the rear frame arm 21, the block 82 also supporting the rear bearings 56, heretofore described. A strut 40 upstanding from the frame arm 21 reinforces this block 82 on the arm 21. It follows that swinging movements of the cradle 11 about the frame pivots rods 53 and 54 are possible with the bevel gears 78 and 80 at each side of the idler 79 remaining in mesh with idler and with the train of mechanisms being interconnected regardless of the position assumed by the cradle 11.

The shaft 81 upstands from the frame arm 21 within the bracket block 82 and a first frame sprocket 83 is mounted on shaft 81 above the fifth bevel gear 80. A chain 84 extends from the sprocket 83 above the arm 21 towards the crotch of the Y-frame to connect with a second sprocket 85 mounted upon the upper section 32 of the spindle 13, on a bearing 33. This second sprocket is interconnected with a third sprocket 86 also mounted upon the spindle section on another bearing 33. The sprocket group 85 and 86 thus idle on spindle 13. A chain 87 extends from this third sprocket 86 to a fourth sprocket 88 which is mounted upon the flywheel shaft 38 to complete the assembly.

The apparatus is simple to operate. Once it is balanced for a passenger, the passenger simply mounts the apparatus in the seat 57, and may secure himself therein with a safety belt 89, as indicated at FIG. 1. Also, a headrest 90, extending above the seat, is desirable to help hold the passenger's head in a fixed position. To commence, he shifts the chain 66 onto any selected pair of sprockets 65 and 67 and simply commences to turn the mechanisms with the foot pedals 62 and thereby commence to rotate the flywheel 35. The rotation of the flywheel effects a counter rotation of the apparatus about the spindle 13. To increase the speed of rotation, the passenger may shift chain 66 to other pairs of sprockets 65 and 67, the same as a bicycle rider shifts the chain on the bicycle sprockets. As the speed of rotation is increased, the passenger's cradle swings outwardly, and the cradle is adapted to swing to an angle of approximately 75 degrees from the vertical rest position. The limiting swing is where the teeth of the third bevel gear 78 commences to contact the teeth of the fifth bevel gear 80. Accordingly, a centrifugal force of approximately twice gravity is possible with the apparatus. To prevent an excessive upswing from clashing the bevel gears 78 and 80, a stop, not shown, may be mounted upon a frame arm 21 adjacent to the bearing, 55 or 56, to contact the end of the cradle arm, 51 or 52.

To stop the apparatus, the operator need only to slow down and stop turning the pedals 62. In a more elaborate construction than that shown, a ratchet mechanism at the pedal, or elsewhere, may be used to permit the train of mechanisms to be disengaged when the passenger stops pedaling and a brake may be used to stop the spinning of the flywheel.

The exerciser E, illustrated at FIGS. 1 to 6, may be easily modified for use in a zero-gravity environment by an actual simplification of the construction of the unit. The exerciser E', illustrated at FIGS. 7 and 8, is exemplary of such modification. The frame 10' and the passenger cradle 11' are rigidly interconnected by welding the arms 51' and 52' to the frame arms 21', and with the arms 51' and 52' lying in the same plane as arms 21'. This modification eliminates pivot rods 53 and 54, bearings 55 and 56 and the idler bevel gear 79. With the respective arms in a common plane, the bevel gear 78 is

directly connected to the bevel gear 80, as illustrated. It is to be noted that the elimination of the idler bevel gear reverses the direction of flywheel rotation with respect to rotation of the foot pedals, and in order to rotate the exerciser forwardly, with respect to the passenger's position, the foot pedals will have to be turned in a direction which is normally backwards. However, if reverse pedaling is undesirable, the second bevel gear 74' may be relocated as to the position indicated in broken lines at FIG. 7 by suitable modifications of the bracket 69 and the shafts 68 and 75.

This apparatus may be mounted in a cylindrical end of a spaceship S to rotate in a plane parallel to the endwall 91 of the ship. The spindle 13 of the apparatus is mounted in a post 14' which, in turn, is mounted at the center of the endwall 91. This post may be rigidly affixed to the ship endwall 91, as by flange 15' attached thereto by bolts 16'. Where the apparatus is mounted in a zero-gravity environment and angular momentum is imparted to it, as by rotation of the flywheel, without any other displacement, the unit will naturally commence rotating about an axis which is a true centroid of the apparatus. The adjustments to the fixed weight 36 will place the centroid of the apparatus as close as possible to the axis of the spindle 13. If this is not done, excessive vibration will be imparted to the spaceship as the exerciser is rotated should the post 14' be rigidly affixed to the wall.

It is important that this apparatus be dynamically balanced when a passenger is mounted in the seat 57, not only with respect to radial centrifugal actions from a centroid as at the axis of the spindle 13, but also with respect to acceleration movements of portions of the system parallel to the spindle axis. This latter action tends to create a wobbling of the exerciser upon the spindle. Accordingly, it is important that the center of gravity of the counterweight assembly at one side of the apparatus and of the passenger's cradle and passenger therewithin at the other side of the apparatus be at diametrically opposing points which would lie on a line which intersects and is normal to the spindle axis. To provide such, the cradle arms 51' and 52' may be provided with offsets 94 to facilitate lining up and balancing the apparatus.

While I have now described my invention in considerable detail, it is obvious that others skilled in the art can build and devise alternate and equivalent constructions which are nevertheless within the spirit and scope of my invention. Hence, I desire that my protection be limited, not by the constructions illustrated and described, but only by the proper scope of the appended claims.

What is claimed is:

1. A centrifugal exerciser mounted upon a spindle and being adapted to rotate freely thereabout, and comprising, in combination therewith, an elongated frame having a spindle mount at its central portion, a cradle at one end of the frame adapted to support a passenger, a counterweight assembly at the other end of the frame adapted to balance the apparatus upon the spindle with a passenger in the cradle, a flywheel carried upon the frame and having its axis parallel to the spindle axis and being adapted to be rotated with respect to the frame in one direction and thereby impart rotation to the frame in the opposite direction, and a manually operable drive means operable by a passenger in the cradle adapted to rotate the flywheel.

2. A centrifugal exerciser mounted upon a spindle and being adapted to rotate thereabout, and comprising, in combination therewith, an elongated frame having a substantially frictionless spindle mount at its central portion, a cradle at one end of the frame adapted to support a passenger, a counterweight assembly at the other end of the frame adapted to balance the apparatus with a passenger in the cradle, wherein the counterweight assembly includes a flywheel having its axis parallel to the spindle axis and being adapted to be rotated with respect to the frame in one direction to impart rotation to the frame in the opposite direction, means on the frame adapted to rotate the flywheel, and said flywheel rotating means extends from the flywheel to the passenger's cradle and includes manually operable driving means whereby the flywheel is rotated manually, as by the efforts of the passenger in the cradle.

3. In the exerciser defined in claim 2, wherein said counterweight assembly includes a fixed weight attached to the frame and adapted to be shifted along the frame, towards and away from the spindle, and set at a selected position on the frame to counterbalance the weight of a specific passenger.

4. In the exerciser defined in claim 2, wherein the spindle is mounted upon a vertical post and the frame is adapted to rotate in a horizontal plane about the post, and wherein the passenger's cradle is pivotally suspended from the frame and is thereby adapted to hang from the end of the frame when the apparatus is not rotating, but is adapted to swing outwardly when the apparatus is rotating about the spindle.

5. In the exerciser defined in claim 4, wherein said frame is Y-shaped with the spindle means being adjacent to the crotch of the Y and with the cradle being formed as a U-shaped frame pivotally suspended between the arms of the Y.

6. In the exerciser defined in claim 2, wherein said frame is Y-shaped with the spindle means adjacent to the crotch of the Y, the cradle is formed as a U-shaped frame suspended between the arms of the Y and includes a passenger seat at one end thereof and driving means in front of the passenger's seat adapted to be operated by the passenger, said driving means being operatively connected to the flywheel and being adapted to rotate the same.

7. In the exerciser set forth in claim 6, wherein said driving means includes a cranking means at the passenger's cradle and a train of mechanisms interconnecting the cranking means and the flywheel.

8. In the exerciser set forth in claim 6, wherein said driving means includes a pedal drive adapted to be turned by the passenger, a train of mechanisms interconnecting from the pedal drive to the flywheel, including sprockets and chain means paralleling the frame.

9. In the exerciser set forth in claim 6, wherein said driving means includes a pedal drive at the base of the passenger cradle, a shaft extending alongside an arm of the cradle to the Y-arm of the frame, a sprocket at the end of the Y-arm interconnected to the shaft by pinions, a sprocket at the flywheel and chain means interconnecting the sprockets.

10. In the exerciser set forth in claim 9, including idler sprockets at the spindle.

11. In the exerciser set forth in claim 6, wherein said frame and passenger's cradle are in a common plane.

12. In the exerciser set forth in claim 6 wherein the passenger's cradle is pivoted to the frame to permit the cradle to hang vertically when the frame is oriented horizontally upon a vertically axised spindle and to swing outwardly from the vertical as the frame is rotated about the spindle.

13. A centrifugal exerciser for a zero-gravity environment, as in a spaceship, and comprising:

a member adapted to be attached to the wall of the ship to normally restrain the apparatus;

an elongated frame having a Y-shaped configuration with a central leg at one side and spreading arms oppositely thereto;

a low-friction bearing attached to the central portion of said frame pivotally engaging said member and having an axis which is normal to the plane of said frame;

a U-shaped passenger-carrying cradle having its arms connected with the ends of the arms of the Y-frame as a continuation thereof;

a counterweight assembly at the outward end of the frame leg including a fixed weight and a flywheel lying in a plane paralleling the plane of rotation, said

counterweight assembly being proportioned to place the centroid of the system substantially at the bearing axis when a passenger is in place in the cradle; and

manually driven means at the passenger's cradle extending to the flywheel, and adapted to be operated by a passenger to rotate the flywheel, whereby rotation of the flywheel imparts a counter rotation of the frame.

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ANTON O. OECHSLE, Primary Examiner

ARNOLD W. KRAMER, Assistant Examiner

U.S. Cl. X.R.

35—12; 244—1; 272—41

US005860808A

United States Patent [19]

Yoshimoto et al.

[11] **Patent Number: 5,860,808**

[45] **Date of Patent: Jan. 19, 1999**

[54] **ROTATING SIMULATOR AND BODY HOLDING APPARATUS THEREFOR**

[75] Inventors: **Maso Yoshimoto**, Kawaki-ku; **Nobushige Ishibashi**, Tokyo, both of Japan

[73] Assignee: **Sega Enterprises, Ltd.**, Tokyo, Japan

[21] Appl. No.: **593,922**

[22] Filed: **Jan. 30, 1996**

Related U.S. Application Data

[62] Division of Ser. No. 667,549, Mar. 11, 1991, Pat. No. 5,489,212.

[30] **Foreign Application Priority Data**

Jul. 2, 1990 [JP] Japan 2-175125/27044

[51] **Int. Cl.**[6] **A63G 31/00**

[52] **U.S. Cl.** **434/55**; 434/29; 434/57; 297/473; 340/457.1

[58] **Field of Search** .... 472/130, 14, 1, 472/2, 16, 30, 32, 45, 3; 24/69 SB, 68 SB, 61.58 B; 297/473; 340/457.1; 434/29, 30, 34, 35, 38, 46, 51, 55, 57–59

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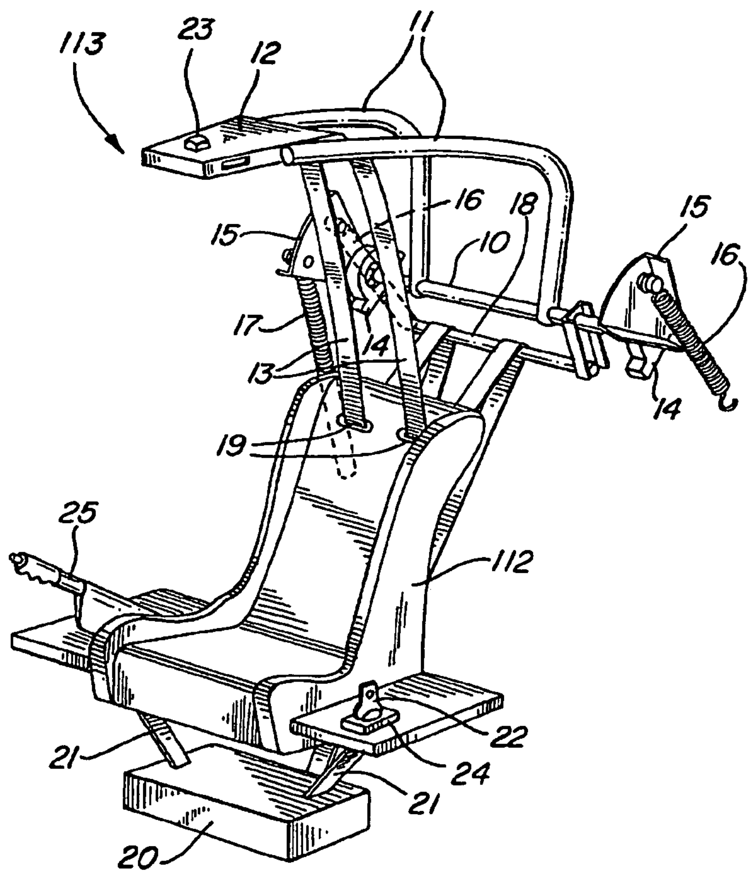
Primary Examiner—Glenn E. Richman
Attorney, Agent, or Firm—Price Gess & Ubell

[57] **ABSTRACT**

Disclosed is a simulator includes a substantially circular outer frame pivotally mounted on a base; an outer frame-driving tire which is pressed against an outer side of the outer frame by means of a spring disposed on the base and is adapted to drive the outer frame, an inner frase formed in a maneuvering seat and pivotally supported between opposing portions of an inner peripheral wall of the outer frame; and an inner frame-driving tire which is pressed against an inner side of the outer frame by means of a spring disposed within the inner frame and is adapted to drive the inner frame. Also disclosed is an occupant holding apparatus for use in the simulator.

9 Claims, 9 Drawing Sheets



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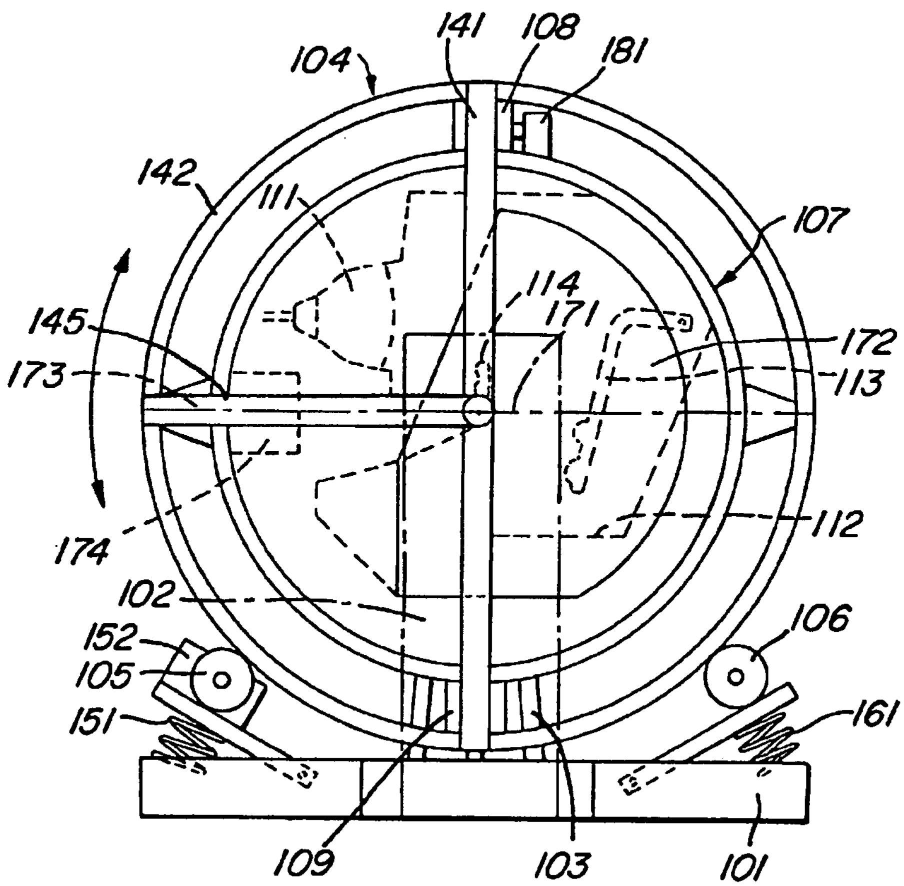
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FIG. 1

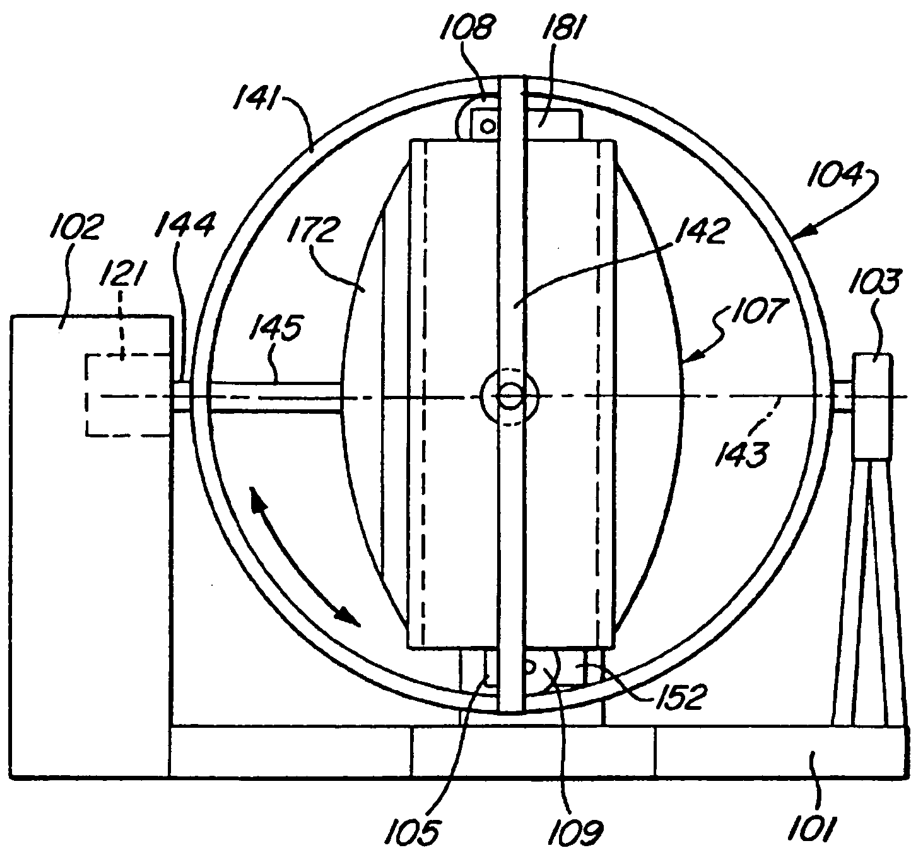
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FIG. 2

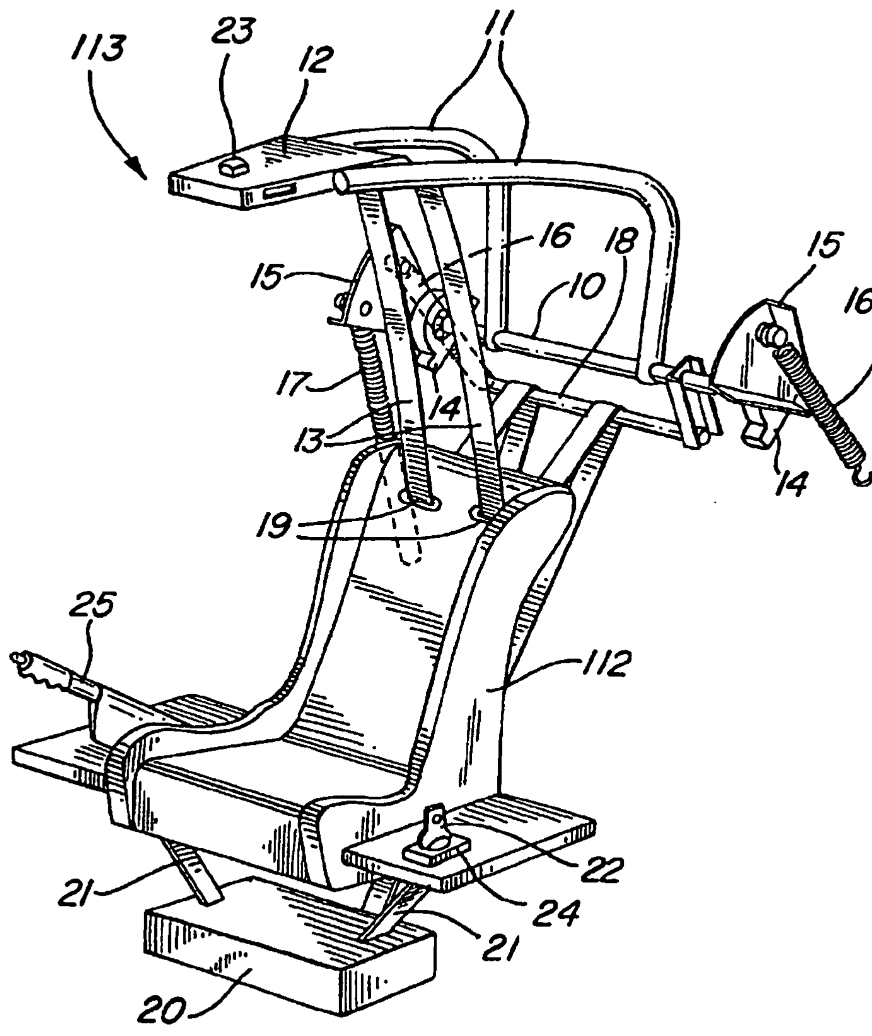

FIG. 3

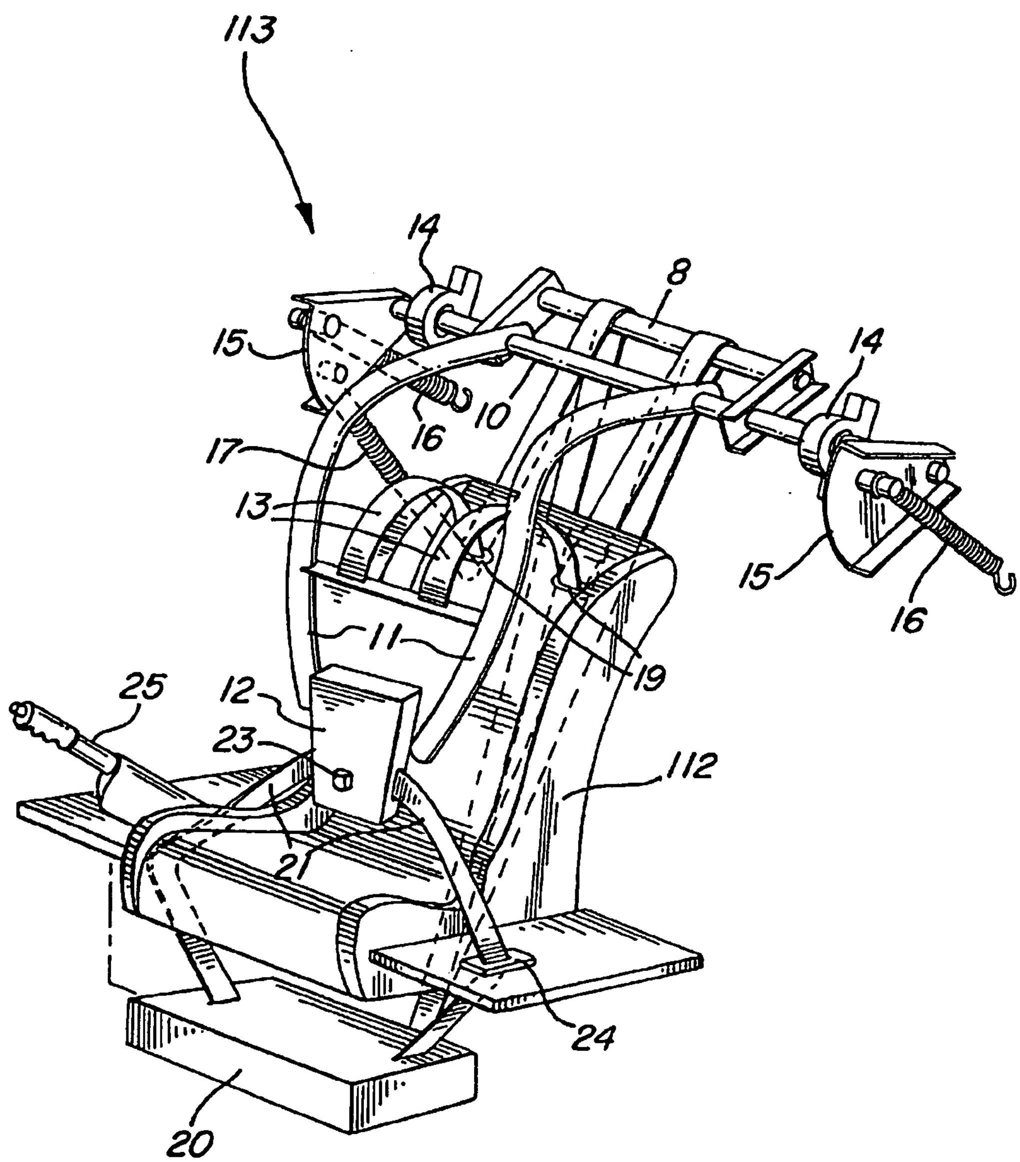

FIG. 4

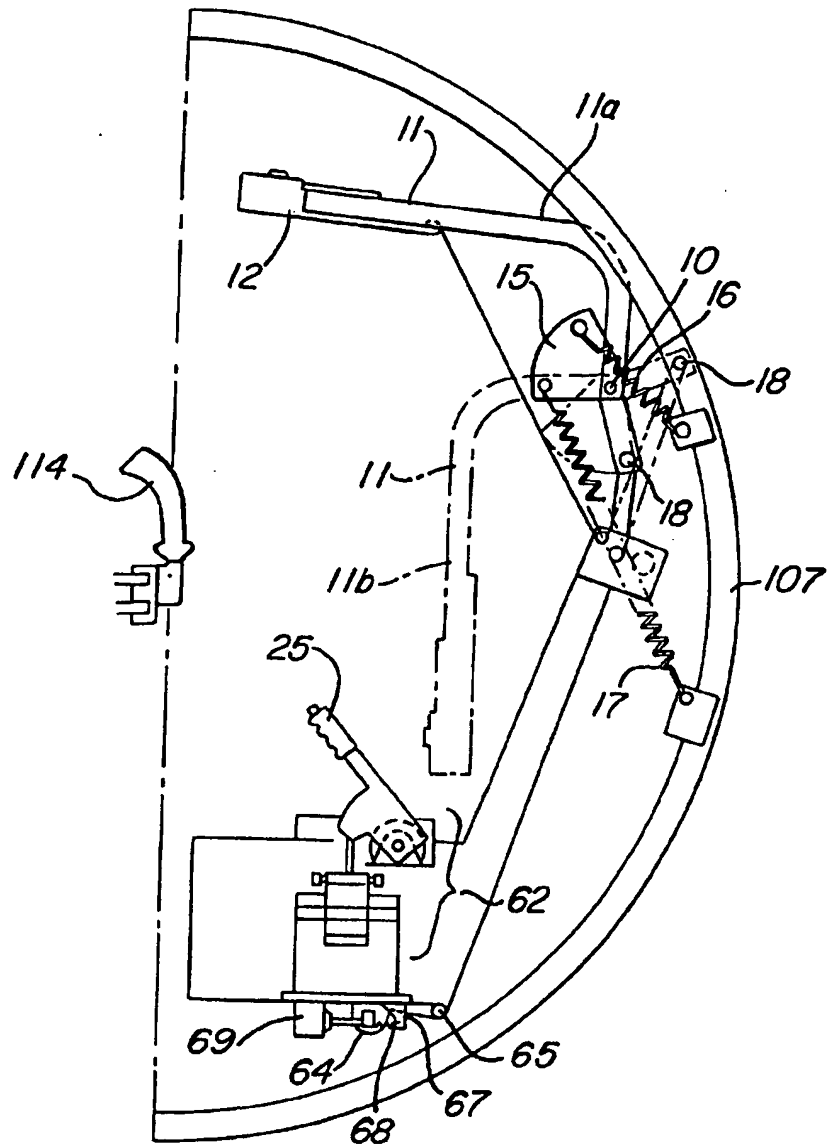

FIG. 5

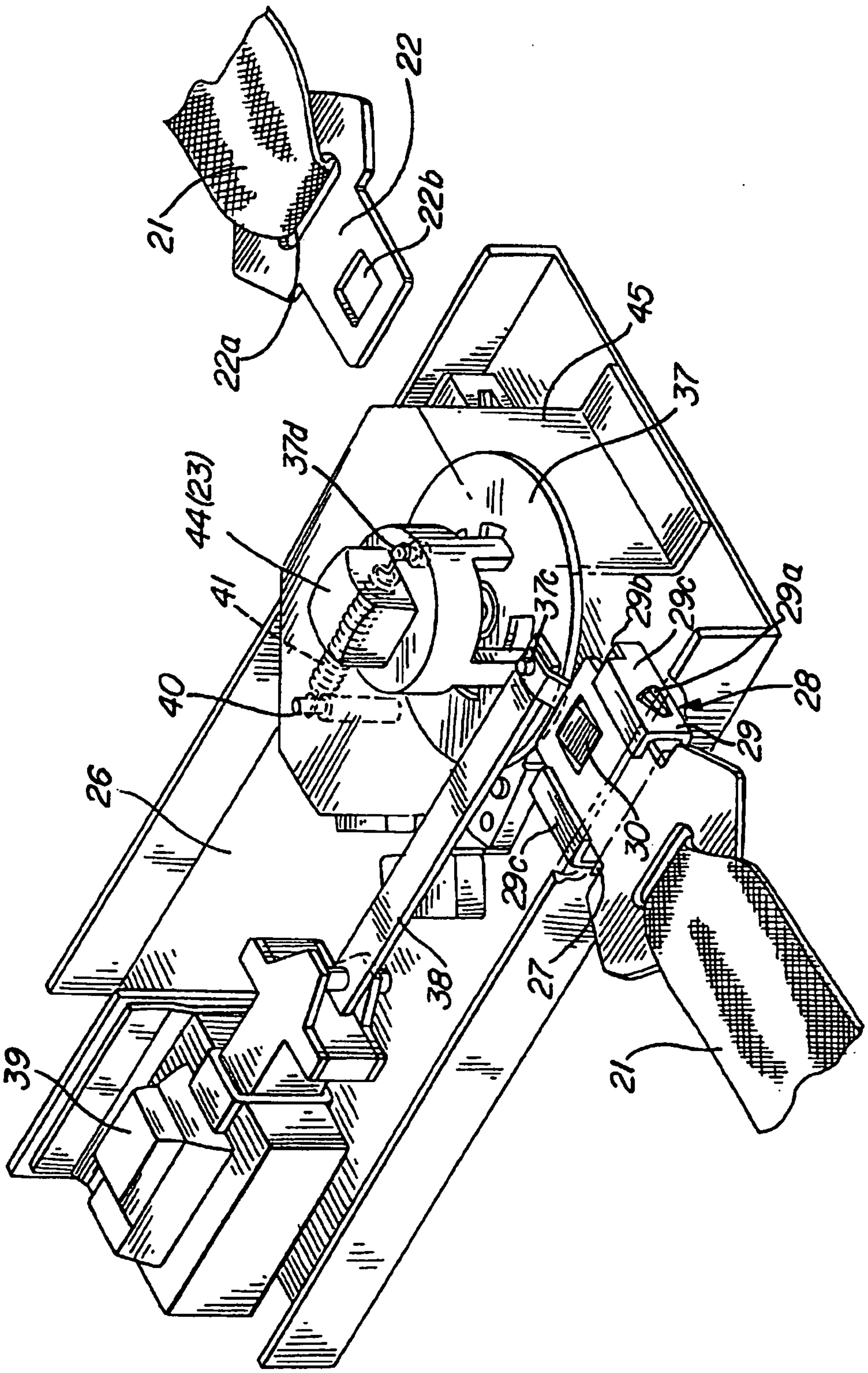
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FIG.6

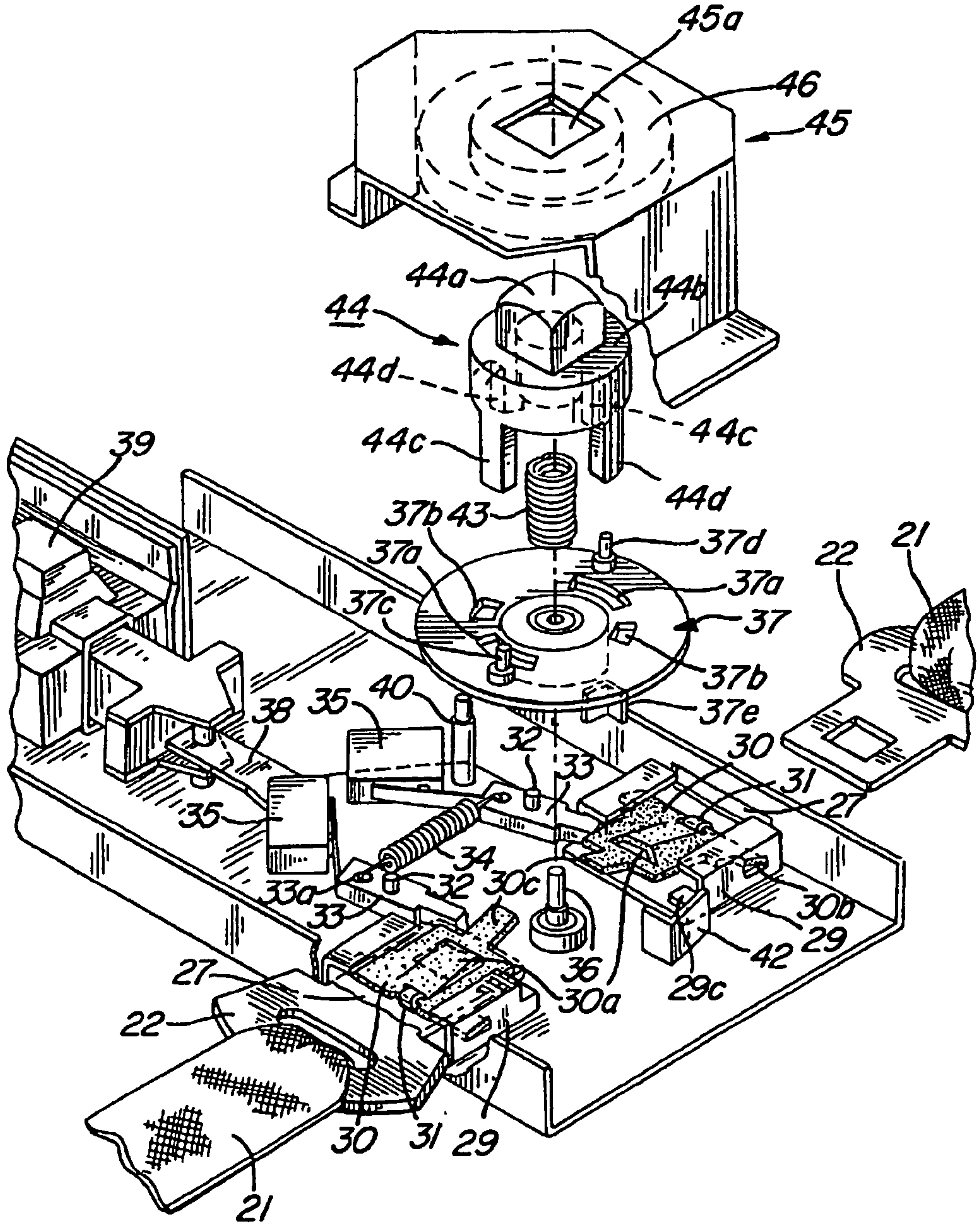
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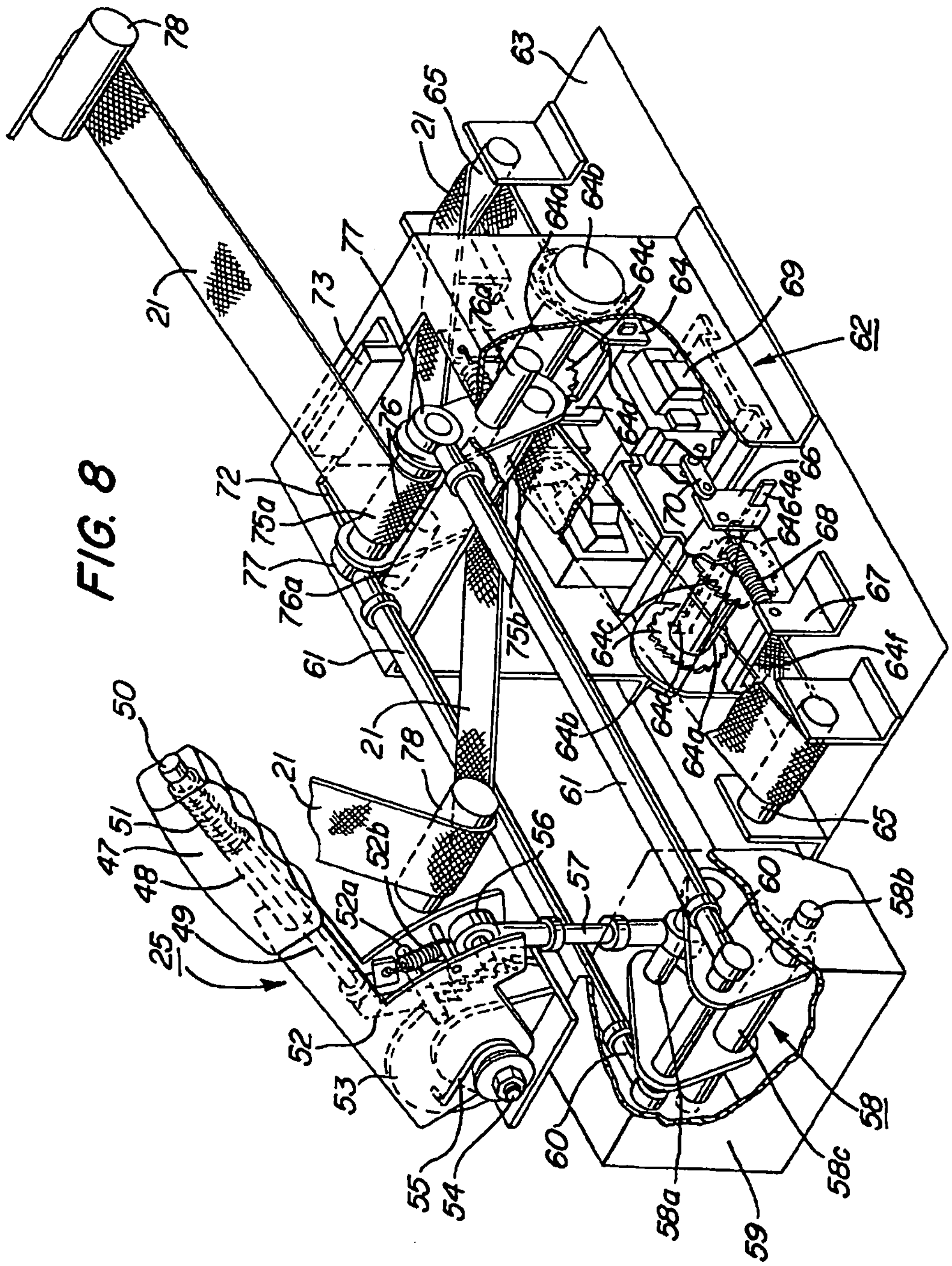
FIG. 7

FIG. 8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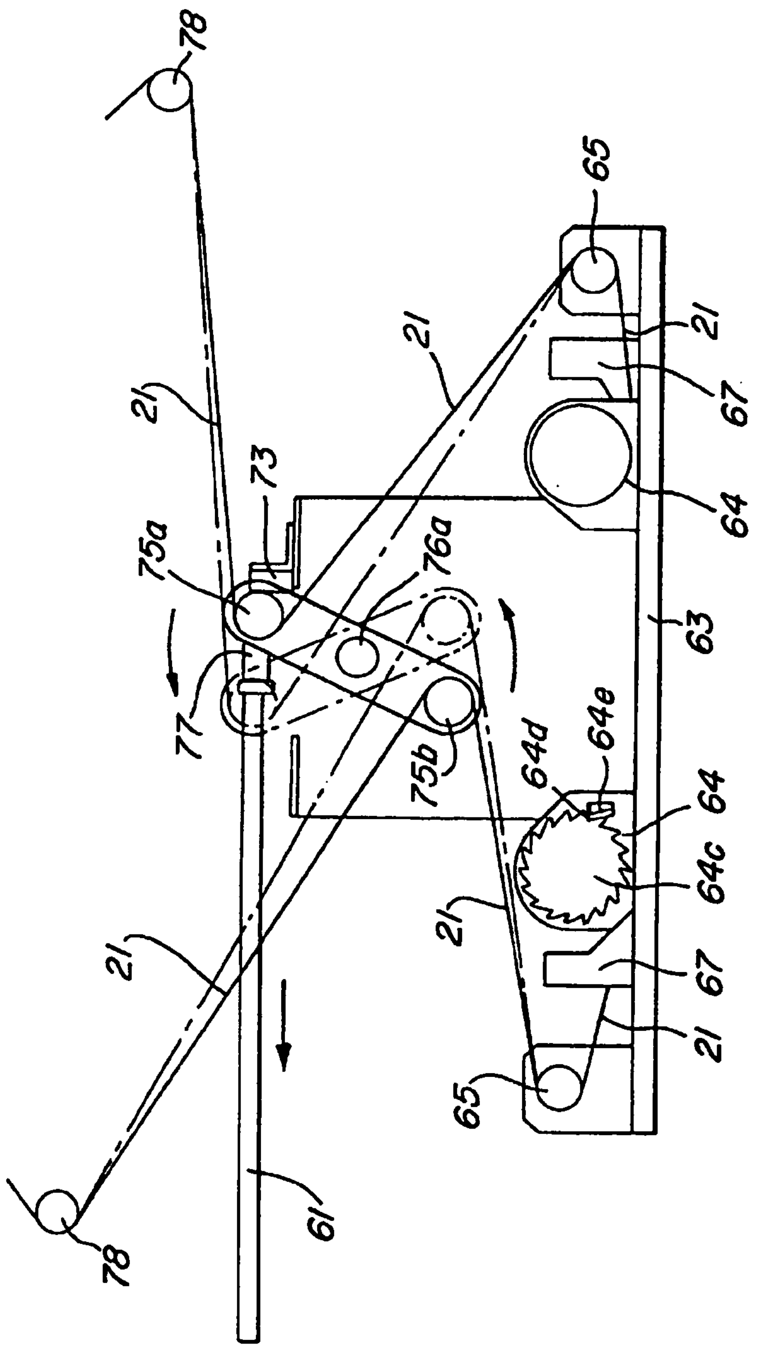

FIG. 9

ROTATING SIMULATOR AND BODY HOLDING APPARATUS THEREFOR

This is a division of prior application Ser. No. 07/667,549, filed on Mar. 11, 1991, now patented, U.S. Pat. No. 5,489,212, for a ROTATING SIMULATION SYSTEM AND BODY HOLDING APPARATUS.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a simulator for simulating the experience of riding a futuristic riding machine or maneuvering a fighter plane, and more particularly to a simulator suitable for a simulation game. In addition, the present invention concerns an occupant holding apparatus for use in such a simulator or a rotating recreational machine adapted to rotate vertically and horizontally.

2. Description of the Related Art

Hitherto, various simulators for use in bodily sensation games have been developed. However, no simulators for games for realizing a 360° turn, such as a vertical somersault or a horizontal somersault, have not been put to practical use.

Japanese Utility Model Application Laid-Open No. 58-180751 can be cited as a conventional occupant holding apparatus for a recreational riding machine such as a jet coaster found in an amusement park or the like.

In the aforementioned invention, there is disclosed an occupant holding apparatus for a recreational riding machine, comprising: an occupant's knee holding bar, a hydraulic cylinder in which a cylinder rod capable of moving forward and backward and having one end pivotally secured to an end of the knee holding bar is slidably inserted; a ropeway pipe having one end connected to the other end of the cylinder rod; a ratchet gear having one end connected to the other end of the ropeway pipe; and an occupant's shoulder holding am secured to a shaft of the ratchet gear.

The occupant holding apparatus disclosed in the above-described embodiment is designed to hold the occupant's shoulder and knee portions. Although it is suitable for a jet coaster or the like, the apparatus is unsuitable as a occupant holding apparatus for use in a recreational machine or simulator adapted to rotate vertically in the place where it is disposed, since it is unable to secure the occupant onto a seat in the state in which the occupant is held upside down.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a simulator capable of allowing an occupant to experience horizontal and vertical somersaults and the like and undergo simulated experience of minus G (gravity), and which permits unconventionally unlimited rotation.

To this end, in accordance with one aspect of the invention, there is provided a simulator comprising: a substantially circular outer frame pivotally mounted on a baser an outer frame-driving tire which is pressed against an outer side of the outer frame by means of a spring disposed on the base and is adapted to drive the outer frame; an inner frame formed in a maneuvering seat and pivotally supported between opposing portions of an inner peripheral wall of the outer frame; and an inner frame-driving tire which is pressed against an inner side of the outer frame by means of a spring disposed within the inner frame and is adapted to drive the inner frame.

Accordingly, in accordance with the present invention, in the case of simulating a role of a pilot of a jet fighter, when

a horizontal somersault is shown on the screen of a cathode ray tube provided in the inner frame, the inner frame constituting the cockpit is rotatively driven by the drive tire to allow the occupant to undergo a horizontal somersault. When a vertical somersault is shown on the screen of the cathode ray tube, the outer frame is rotatively driven by the drive tire, with the result that the inner frame constituting the cockpit is rotated in the manner of a vertical somersault.

Another object of the present invention is to provide a body holding apparatus for firmly scouring an occupant even in a state in which he or she is held upside down.

To this end, in accordance with another aspect of the invention, there is provided an occupant holding apparatus for a rotating recreational machine, comprising: a seat belt tip holding mechanism disposed at a distal end of an occupant holding arm for holding a frontal portion of the occupant, said occupant holding arm being vertically openable between a frontal upper side of a seat of said rotating recreational machine and a waist portion of the occupant with a horizontal axis in the rear of a head portion of said seat being set at a rotational axis. Tongues of a pair of seat belts for a waist secured to and paid out from transversely opposite sides of an underside of said seat are fitted with said seat belt tip holding mechanism.

Furthermore, in this occupant holding apparatus, a pair of seat belts for shoulders are secured at one ends thereof to a distal end of an occupant holding arm in such a manner that said seat belts are spaced apart a distance of the occupants shoulders. The seat belts are passed through belt holes provided in a back portion of a seat with an interval corresponding to the length of the occupant's shoulders. The seat belts are passed around an auxiliary shaft occured to a rotating shaft of said occupant holding arm and behind a back of said seat, said rotating shaft of said occupant holding arm being located in the rear of said occupant holding arm. The gear belts are held under tension by being connected to a belt takeup mechanism disposed on an underside of said seat.

Additionally, in this occupant holding apparatus, the pair of seat belts for a waist are secured at one ends thereof to a pair of takeup mechanism provided on transversely opposite sides of an underside of said seat, said pair of seat belts for a waist are paid out from the pair of takeup mechanisms via a belt tightening mechanism and passed around transversely opposite sides of said seat, and said pair of seat belts for a waist are detachably held by said seat belt tip holding mechanism.

Furthermore, in this occupant holding apparatus, a pair of turn rollers are provided for the seat belts for shoulders and a pair of seat belt direction-converting portions provided on opposite sides of said seat, and a pair of belt takeup are disposed below said pair of direction-converting portions, respectively. A belt tightening mechanism is disposed in a substantially intermediate position between said pair of direction-converting portions and said pair of takeups, and includes a pair of rollers arranged in parallel with each other and rotatably supported by a pair of elongated plates at opposite ends thereof, said belt tightening mechanism being rotatable about the center of each of said elongated plates. The pair of seat belts are wound around said pair of rollers, respectively. One ends of said pair of elongated plates are connected to one end of a seat belt tightening lever by means of a coupling mechanism. The tightening mechanism is adapted to be rotated by said rotating shaft by an operation of said seat belt tightening lever so as to tightenably support said seat belts of a waist by increasing the distance between

the direction-converting portions for the seat belts for a waist and the respective takeups.

As a tongue insertion detecting means for detecting the insertion of a tongue into a retainer for retaining the tongue provided at the tip of the seat belt, a contacting piece is provided, and the operation of the contacting piece may be detected by a limit switch or a photocoupler.

In addition, in the occupant holding apparatus for a rotating recreational machine, said seat belt tip holding mechanism may comprise: a button member having a leg for depressing a projecting piece provided on said retainer; and a movable plate, such as a movable disk or a slidable plate, having a slot and disposed between said button member and said projecting piece. The movable plate is rendered movable by a driving portion, such as a solenoid coil or a hydraulic or air cylinder, connected to said movable plate. The leg of said button member is arranged to be capable of depressing said projecting piece of said retainer in conjunction with the movement of said movable plate so as to release said tongue from said retainer.

The occupant holding apparatus for a rotating recreational machine may further comprise a belt takeup mechanism in which a driving portion is provided in the rear of said bolt takeups, and a ratchet pawl of each of said belt takeup is made disengageable from a ratchet pawl thereof by means of said driving portion.

The other objects, features and advantages of the invention will become more apparent from the following detailed description of the invention when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevational view illustrating a simulator in accordance with an embodiment of the present invention;

FIG. 2 is a side elevational view of the same;

FIG. 3 is a diagram illustrating an initial state of an occupant holding apparatus;

FIG. 4 is a diagram illustrating a state in which the apparatus is being applied to the occupant;

FIG. 5 is a side elevational view of the apparatus;

FIG. 6 is a perspective view of a buckle mechanism;

FIG. 7 is an exploded perspective view of the mechanism;

FIG. 8 is a perspective view of a mechanism for tightening seat belts for the waist; and

FIG. 9 is a front elevational view of the mechanism.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the accompanying drawings, a description will be given of a preferred embodiment of a simulator in accordance with the present invention. In FIGS. 1 and 2, a base **101** constitutes a support for a simulator, and has a substantially octagonal configuration formed of a large, thick plate.

A columnar control box **102**, which also serves as a bearing, is formed uprightly on a periphery of the base **101**. An unillustrated controller is accommodated in the control box **102**.

A bearing support column **103** is formed uprightly on a peripheral portion of the base **101** in face-to-face relationship with the control box 102.

An outer frame **104** comprises a large pivot ring **141** pivotally supported between the control box **102** and the support column **103** which together form a pair, and a similarly large drive ring **142** secured orthogonally to the pivot ring **141**.

An arcuate arm **145** for a electric power supply line and a signal line is secured between a portion of the pivot ring **141** located close to the control box **102** and the drive ring **142**.

A drive tire **105** for driving the outer frame **104** is pressed against an outer side of the drive ring **142** by means of a spring **151** disposed on the base **101**. An electric motor **152** is used to drive the drive tire **105** so as to rotatively drive the outer frame **104** about a fixed axis **143**.

An auxiliary tire **106** is provided as required, and is used to stabilize the rotation of the outer frame **104**. The auxiliary tire **106** is pressed against the outer side of the drive ring **142** by means of a spring **161** disposed on the base **101**.

An inner frame **107** is formed into a hollow, substantially disk-shaped cockpit and is pivotally supported by opposing portions of an inner peripheral wall of the drive ring **142**.

A drive tire **108** for driving the inner frame **107** is pressed against an inner side of the pivot ring **141** by means of a spring (not shown) disposed in the inner frame **107**. An electric motor **181** is used to drive the drive tire **108** so as rotatively drive the inner frame **107** about a moving axis **171**.

An auxiliary tire **109** is provided as required, and is used to stabilize the rotation of the inner frame **107**. The auxiliary tire **109** is pressed against an inner side of the pivot ring **141** by means of a spring (not shown) provided in the inner frame **107**.

It should be noted that although the drive tire **108** and the electric motor **181** are disposed on an upper side of the inner frame **107**, it goes without saying that these members may be disposed on a lower side of the inner frame **107** by replacing the drive tire **108** with the auxiliary tire **109**. In addition, no particular problem is presented in practical use even it the auxiliary tire **109** is omitted.

A door **172** is provided openably in a control box **102** side peripheral wall of the inner frame **107** which is a hollow, substantially disk-shaped cockpit. Accommodated in the inner frame **107** are a cathode-ray tube **111**, a seat **112**, a body holding arm **113** for safety, a control stick **114**, and the like.

The electric power supply line for the overall apparatus is connected to the electric motor **181**, the cathode-ray tube **111** and the like via a rotary connecting device **121** in the control box **102**, a fixed-axis shaft **144**, the arm **145**, a moving-axis shaft **173**, a rotary connecting device **174** in the inner frame **107**, and the like.

It goes without saying that the signal line for a controller (not shown) such as a CPU is connected in the same way at the aforementioned electric power supply line.

In the operation of this embodiment arranged as described above, a player, i.e., an occupant, opens the door **172** and is seated in the seat **112**. The occupant then wears the body holding arm **113**, closes the door **172**, and presses an unillustrated start button. Then, an image on the cathode-ray tube Ill changes. For instance, in the case of playing the role of a pilot of a jet fighter, when a horizontal somersault in shown on the screen, the inner frame **107**, i.e., the cockpit, is rotated by the electric motor **181** and the drive tire **108** as shown by the double-headed arrow in FIG. 2. Meanwhile, when a vertical somersault is shown on the screen, the outer frame **104** is rotated by the electric motor **152** and the drive tire **105** as shown by the double-headed arrow in FIG. 1. As

a result, the inner frame **107**, i.e., the cockpit, is rotated as shown by the double-headed arrow shown in FIG. **1**.

It goes without saying that the relationship between the image on the cathode-ray tube **111** and the rotation of the inner and outer frames **107**, **104** need not be made to correspond with each other on a one-to-one basis, and that an optical illusion of human beings may be made use of.

Thus, the embodiment arranged as described above offers the advantage that the simulator with a very simple arrangement allows an occupant to experience horizontal and vertical somersaults, undergo a simulated experience of minus G, and experience unlimited rotation.

FIG. **3** illustrates an initial state of an occupant holding apparatus **113** for use in the simulator in accordance with the present invention. FIG. **4** illustrates a state in which the occupant holding apparatus **113** is applied to the occupant. The occupant holding apparatus **113** is mounted in a cockpit portion of the inner frame **107**.

As shown in FIG. **4**, the occupant holding apparatus **113** is arranged as follows. Upper ends of a pair of breast holding arms **11**, which are curved in an L-shaped configuration as viewed from their side and are disposed in a substantially V-shaped configuration as viewed from their front, are spaced apart a distance substantially corresponding to the length of the occupant's shoulders and are secured to a shaft **10** hold in such a manner as to be rotatable about a horizontal axis in the rear of the occupant's head in order to hold the occupant seated in a bucket-type seat **112**.

A buckle look mechanism **12** is disposed at a lower end of a triangular portion formed between the pair of breast holding arms **11**, while a pair of seat belts **13** for holding the occupants shoulders are spaced apart a distance substantially corresponding to the length of the occupant's shoulders, and one ends of the seat belts **13** are secured to an upper portion of the buckle lock mechanism **12**. The pair of breast holding arms **11** are thus secured to the shaft **10**. The shaft **10** has its opposite ends pivotally supported by the inner frame **107**, i.e., the frame of the cockpit, by means of a pair of bearings **14**, as shown in FIG. **4**. The pair of breast holding arms **11** can be pushed upwardly on the front side of the occupant as they are rotated about type shaft **10** placed horizontally, as shown in FIG. **3**. Proximal portions of a pair of fan-shaped members **15** are secured to opposite ends of tho shaft **10**. Each of a pair of tensile springs **16** has one end connected to an arcuate distal end portion of each fan-shaped member **15** and the other end to a portion of the cockpit portion **107** located in the rear of the shaft **10**. Hence, when the breast holding arms **11** are pushed upwardly to the vicinity of a fully open position at an angle substantially orthogonal to a closed position, the tensile springs **16** urge the breast holding arms **11** in the opening direction, and urge them in the closing direction when they are at a position different from the aforementioned position. Furthermore, one end of a damper spring **17** is connected to a lower end of the arcuate distal and portion of the left-hand tan-shaped member **15**, and the other end thereof is connected to the rear of the back of the seat **112** of the cockpit portion **107**, so that the breast holding arms **11** are constantly urged upwardly. Thus, the damper spring **17** facilitates the opening and closing operation of the breast holding arms **11** in cooperation with the pair of tensile springs **16**.

An auxiliary shaft **18** which is parallel with the shaft **10** secured to the side of the shaft **10** which is opposite to the side to which the breast holding arms **11** are secured. The seat belts **13** for shoulders are passed through belt holes **19** provided in a shoulder portion of the seat **112**.

The other ends of the seat belts **13**, after being passed around the auxiliary shaft **18**, are accommodated in a retractor **20** placed underneath the seat **112**.

Since the auxiliary shaft **18** is secured to the opposite side of the breast holding arms **11**, the auxiliary shaft **18** remains lowered to the vicinity of the belt holes **19** in a fully open state **11***a* (FIG. **3**) of the breast holding arms **11**, as shown in the side elevational view of the occupant holding apparatus illustrated in FIG. **5**. On the other hand, in a closed state **11***b* (FIG. **4**) of the breast holding arms **11**, the auxiliary shaft **18** remains at a position distant from the belt holst **19** and the retractor **20**. In other words, if the breast holding arms **11** are moved from the open state to the closed state, the effective length of the seat belts **13** for shoulders is increased by a portion of the reciprocating distance of the auxiliary shaft **18** when the auxiliary shaft **18** moves upwardly with the rotation of the shaft **10**. The seat belts **13** are thus paid out from the retractor **20** and tighten the shoulders of the occupant. On the other hand, when the breast holding arms **11** are opened from the closed state, the seat belts **13** are loosened.

The buckle lock mechanism **12** is used to render detachable a pair of tongues **22** of seat belts **21** for the waist provided on the left and the right of the seat **112**, one ends of the seat belts **21**, i.e., the tongues **22**, being engaged with the buckle lock mechanism **12** for securing the waist of the occupant. The arrangement provided is such that the seat belts **21** for the waist can be removed from the buckle lock mechanism **12** by pressing a button **23** provided on the buckle look mechanism **12**. The other ends of the seat belts **21** for the waist, after being passed through belt holes **24** provided in opposite side plates of the seat **112**, are respectively accommodated in the retractor **20**. After the tongues **22** of the seat belts **21** for the waist are engaged with the buckle lock mechanism **12**, the seat belts **21** can be tightened by operating a belt tightening lever **25** provided on the right-hand side of the seat **112**.

FIG. **6** illustrates a perspective view of the buckle lock mechanism, and an exploded perspective view of the mechanism is shown in FIG. **7**. Each seat belt **21** for the waist is fixed in a transverse slot **22***a* of the tongue **22**, and a tip of the tongue **22** has a smaller width than a rear-end portion thereof and is formed into a rectangular configuration, a rectangular hole **22***b* being provided in the tip thereof.

The buckle lock mechanism **12** is arranged such that opposite sides of a mounting base **26** are bent, a pair of rectangular tongue insertion holes **27** are respectively provided in bent side plates, and a buckle holding mechanism **28** is provided in each tongue insertion hole **27**.

The buckle holding mechanism **28** is arranged in the same way as that of an automobile seat belt, and its cross section has a configuration in which legs of a staple are bent inwardly. As shown in FIG. **7**, each of a pair of retaining portions **30***b* of a projecting retainer **30** is movably held in a hole **29***a* provided in a lower portion of each opposite side plate of a holder **29** into which the tip of the tongue **22** is inserted. In addition, each of a pair of tongue supporting pieces **29***b* whose height is half the height of the side plate of the holder **29** is provided at the farther end of each side plate of the holder **29** in such a manner as to project inwardly. A stepped projecting portion **50***a* is provided on a central portion of the retainer **30**, and the pair of retaining portions **30***b* are provided on transversely opposite base portions of the retainer **30**, respectively. A leaf spring **31** is provided on a central lower portion of the base portion of the retainer **30** so as to urge the retainer **30** downwardly, i.e., to press the retainer **30** toward the bottom surface of the holder **29**.

Accordingly, if the tip of the tongue **22** is inserted into the holder **29** through the tongue insertion hole **27**, the tongue is slid while being clamped by an upper side **29***c* of the holder **29** and the retainer **30** until it is placed on the tongue supporting pieces **29***b*, When the tongue **22** is inserted up to the innermost portion of the holder **29**, the stepped portion **30***a* of the retainer **30** is released from the downward pressure by means of the rectangular hole **22***b* of the tongue, and is lifted upwardly by means of the resilient force of the leaf spring **31**. As a result, the stepped portion **30***a* is latched in the rectangular hole **22***b* of the tongue.

Furthermore, two shafts **32** are embedded in the mounting base in the vicinity of farther corners of the holders **29**, respectively. A contacting piece **33** transversely elongated relative to the longitudinal direction of the tongue **22** is rotatably held by each shaft **32** at a height for coming into contact with a shoulder portion of each retainer **30**. The other end of each contacting piece **33** is provided with a hole **33***a*. A tensile spring **34** is fixed in these holes **33***a* so as to pull the contacting pieces **33**. A limit switch **35** is provided on the side of the end of each contacting piece **33** where the hole is provided. Accordingly, when the tongue **22** is not retained by the retainer **30**, the contacting piece **33** is placed on the shoulder portion of the retainer **30**. When the tongue **22** is inserted into the tongue insertion hole **27** and is retained by the retainer **30**, the contacting piece **33** is pushed by the tip of the tongue **22**, and moves about the shaft **32**. The movement of the contacting piece **33** overcomes the resilient force of the tensile spring **34**, and turns on the limit switch **35** provided on the side of the holder **29** where the tongue **22** has been inserted. Although the contacting piece **33** is disposed between the retainer **30** and the limit switch **35**, a contactor of the limit switch may be brought into direct contact with the shoulder portion of the retainer **30**, or the insertion of the tongue **22** may be detected by means of a photocoupler.

A description will now be given of a mechanism for removing the tongue **22** from the retainer **30**. A pivot **36** is embedded in an intermediate position between the two holders **29**. A disk **37** whose diameter extends such as to span the holders **29** is rotatably mounted on the pivot **36** without contacting the holders **29** and the retainers **30**. Two sets of slots **37***a*, **37***b* are provided in the disk **37** in the circumferential direction thereof so as to be located immediately above projections **30***c* provided on the tips of the retainers **30**, respectively. The slot **37***a*, located immediately above the projection **30***c* and mating with the slot **37***b*, is configured in such a manner as to arcuately extend counterclockwise with respect to the projection **30***c* when the projection **30***c* is viewed from the disk side. The mating slot **37***b* is located at a position spaced apart clockwise with respect to the position of the projection **30***c*, and has a width corresponding to the width of the projection **30***c*. The other set of slots are arranged symmetrically about the center of the disk with respect to the above-described set of slots.

Supporting shafts **37***c*, **37***d* an embedded in tho disk on the outer side of the slots **37***a*, and an elongated connecting member **38** is fixed to the supporting shaft **37***c* on this side and is connected to a solenoid coil **39** mounted in the rear of the mounting base **26**. As the solenoid coil **38**, a hydraulically or pneumatically operated cylinder may be used instead. In addition, a tensile spring **41** is stretched between the supporting shaft **37***d* and a supporting shaft **40** embedded on the right-hand side of the right-hand side limit switch **35**, so as to constantly urge the disk **37** counterclockwise.

A retaining piece **37***e* is provided on a peripheral portion of the rear side of the disk **37** and abuts against a retaining piece **42** secured to the mounting base, so that the retaining piece **37***e* does not rotate further counterclockwise, This is the position in which the projection **30***c* of the retainer is located on the side of the notch **37***a* which is close to the notch **37***b*.

A pushbutton **44** is located in the center of the disk **37** via a compression spring **43**. The pushbutton **44** is arranged such that its upper side is formed into a square column **44***a* and its lower side into a cylindrical column **44***b*. The diameter of the cylindrical column **44***b* is of a size which is within a circle defined by the outer edges of the notches **37***a*, **37***b*. Two long legs **44***c* and two short legs **44***d* penetrating the notches **37***a*, **37***b* are provided on the lower side of the cylindrical column **44***b*. Each of the long legs **44***c* penetrates the notch **37***b* side of the notch **37***a* down to the vicinity of the projection **30***c* of the retainer. The length of each of the short legs **44***d* is set in such a manner as to sufficiently enable the long legs **44***c*, when lowered, to push down the projection **30***c* of the retainer so as to disengage the tong **22** from the retainer **30**. The long legs **44***c* and the short legs **44***d* are provided at positions corresponding to quarters of a circumference, respectively. The short legs **44***d* abut against the disk surface clockwise adjacent the notch **37***b* of the disk. Accordingly, in this state, even if the pushbutton **44** is pushed, the tongue **22** cannot be disengaged from the retainer **30**.

Since the compression spring **43** is disposed between a central portion of the disk and an upper interior of the cylindrical column of the pushbutton, the pushbutton **44** is constantly urged upwardly. A square hole **45***a* conforming with the upper square column **44***a* of the pushbutton is provided in a central portion of a guide plate **45** set upright on the mounting base **26**. A button guide **46**, formed of a hollow short cylindrical column in conformity with the lower cylindrical column of the pushbutton, is provided around the square hole **45***a*. Thus, the pushbutton is mounted in such a manner as to be slidable vertically without rotating.

Here, if both of the tongues **22** are inserted into the holders **29**, the tips of the tongues press the respective contacting pieces **33**, which, in turn, turn on the limit switches **35**. Thus, it is possible to detect that the occupant has worn the seat belts **21** for the waist, whereupon the simulator, or a rotating recreational machine, is ready to start its operation.

When the play is completed and the seat returns to the starting position, the solenoid coil **39** is energized. The solenoid coil **39** then pulls the connecting member **38** connected thereto, and the connecting member **38**, in turn, rotates the disk **37** clockwise by overcoming the tensile spring **41**, so that the disk is offset clockwise by the portion of the notch **37***b*. At this stage, if the pushbutton **44** is pressed, the long legs **44***c* are positioned on the opposite aides of the notches **37***a*, respectively, and the short legs **44***d* can penetrate the notches **37***b*. Then, the pushbutton **44** is pushed downwardly by overcoming the compression spring **43**, and the long legs **44***c* push down the projections **30***c* of the retainers. As each of the projections **30***c* is lowered, the stepped portion **30***a* is disengaged from the square hole **22***b* in the tip of the tongue, and the contacting piece **33** acts in the direction of pushing back the tongue **22** by means of the pulling-back force of the tensile spring **34**, thereby pushing out the tongue **22**. Accordingly, the contacting piece **33** remains positioned on the shoulder portion of the retainer, turning off the limit switch **35**. Thus, when the pushbutton **44** is pressed, the lower two long legs **44***c* of the pushbutton **44** push down the projections **30***c* of the retainers, respectively, thereby disengaging the tongues **22**.

When the tongue **22** is inserted again into the tongue insertion hole **27** so as to be secured by the retainer **30**, the energization of the solenoid coil **39** is stopped. Then, the disk **37** is returned counterclockwise by means of the action of the tensile spring **41** and is held at a position where the retaining piece **37e** on the rear side of the disk and the retaining piece **42** on the mounting base abut against each other. In this state, even if the pushbutton **44** is pressed, it cannot be pressed down, so that the tongue **22** cannot be removed. This measure is adopted because it is very dangerous to remove the tongue **22** by pressing the pushbutton **44** during the operation of this rotating recreational machine.

Although the rotating disk **37** is used in this embodiment, it is possible to adopt the following arrangement: Instead of the rotating disk **37**, a rectangular plate of a size which spans the holders **29** is provided with notches each located immediately above the projection **30c** of the tongue. The rectangular plate is mounted slidably in the transverse direction relative to the longitudinal direction of the buckle **22**. The rectangular plate is connected at its one end to the solenoid coil **39**, and the other end of the rectangular plate is urged by a tensile spring. The arrangement provided is such that the long legs of the pushbutton can be engaged at the notches of the rectangular plate.

When the occupant is seated in the seat **112**, the breast holding arms **11** are lowered to fit his or her body. Simultaneously with this operation, the seat belts **13** for shoulders are paid out over his or her shoulders via the belt holes **19** provided in the back of the seat, and reach the occupant's breast. As the breast holding arms **11** are lowered, the auxiliary shaft **18** is raised upwardly, thereby tightening the seat belts **13**, for shoulders. Furthermore, the occupant pulls the seat belts **21** for the waist and cause them to be locked by the buckle lock mechanism **12**. The occupant then pulls up the belt tightening lever **25** provided on his or her right-hand side of the seat so as to tighten the seat belts **21** until they fit his or her waist.

FIG. **8** illustrates a perspective view of a mechanism for tightening seat belts for the waist, and FIG. **9** illustrates a front elevational view of essential portions of the mechanism.

The belt tightening lever **25** is similar to a lever employed for a side brake of an ordinary automobile.

Specifically, a piston rod **49** is provided in a cylinder **48** of a grip **47** in such a manner as to be slidable in the longitudinal direction. A lever releasing button **50** is attached to a distal end of the piston rod **49**. A compression spring **51** is provided between the cylinder **49** of the piston rod **49** and the lever releasing button **50**. The piston rod **49** abuts against a ratchet pawl **52**, which is mounted on a shaft **52a** and abuts against a ratchet gear **53** by being urged by a tensile spring **52b**. The belt tightening lever itself is urged downwardly by a helical spring **55** wound around a gear shaft **54**. Since the ratchet gear **53** is retained by the ratchet pawl **52**, the belt tightening lever **25** is prevented from being lowered in this state.

Upon pressing the lever releasing button **50**, the piston rod **49** is pushed, which in turn pushes the ratchet pawl **52**, so that the pawl is disengaged from the ratchet gear **53**, thereby making it possible to lower the belt tightening lever **25**. If tho occupant releases his or her finger from the lever releasing button **50**, the lever releasing button **50** returns to its original position by means of the resilient force of the compression spring **51**. As a result, the piston rod **49** is pulled back, and the ratchet pawl **52** is engaged with the ratchet gear **53** by means of the resilient force of the tensile spring **52b**, thereby holding the belt tightening lever **25** in that position.

An upper end of a connecting rod **57** is connected via a rod end **56** to a shaft mounted transversely between opposite side plates of a lower portion of the belt tightening lever **25**. A lower end of the connecting rod **57** is fixed via a rod end to a central portion of a mounting shaft **58a** disposed at an end of a bell crank **58**. Thus, the vertical motion of the belt tightening lever **25** is transmitted to the bell crank **58**.

The bell crank **58** is arranged as follows: Two plates both shaped into a rectangular equilateral triangle are arranged in parallel with each other in such a manner as to be rotatable about a rotating shaft **58b** which is secured in their right-angled portions and is pivotally supported in side plates of a bracket **59**. A pair of horizontal rods **61** are respectively mounted via rod ends **60** on opposite ends of a mounting shaft **58c** penetrating the vicinity of an upper apex of the bell crank **58**. The horizontal rods **61** at the other ends are secured to the belt tightening mechanism **62**.

The belt tightening mechanism **62** is located below the seat **112**, and a pair of retractors **64** of ELR (emergency looking retractor) seat belts are provided transversely symmetrically on the left- and right-hand sides of a rectangular mounting base **63**. The retractor **64** is arranged to take up the seat belt onto it by means of a spiral spring **64b** disposed on an outer side of a takeup shaft **64a**. A pair of ratchet gears **64c** are respectively secured to opposite ends of the takeup shaft **64a** interiorly of a pair of brackets provided for the takeup shaft **64a**. A transversely elongated member **64e** provided with a ratchet pawl **64d** for meshing with the ratchet gear **64c** extends between the brackets. One end of the ratchet pawl **64d** projects outwardly of the bracket, so that the ratchet pawl **64d** can engage or disengage with the ratchet gear **64c**.

A turn roller **65** is provided outside a seat belt takeup port **64f** of the retractor **64**. A rectangular member **66** with one corner cut off is mounted on the transversely elongated member **64e** projecting from one side of the retractor **64**. A tensile spring **68** is stretched between one end of the rectangular member **66** and a support member **67** mounted on the mounting base at a position close to the seat belt takeup port **64f** of the retractor. A solenoid coil **69** is secured to the mounting base **63** on the opposite side of the support member **67** with the rectangular member **66** placed therebetween. The solenoid coil **69** is connected to an upper end of the rectangular member **66** by means of a connecting member **70**. When the solenoid coil **69** is energized, the connecting member **70** is pulled to incline the transversely elongated member **64e** via the rectangular member **66**, thereby disengaging the ratchet pawl **64d** from the ratchet gear **64c**. Thus, it is possible to release the takeup shaft **64a** and pull out the seat belt freely by overcoming the spiral spring **64b**. When the energization of the solenoid coil **69** is stopped, the rectangular member **66** is inclined toward the support member **67** by the tensile force of the tensile spring **68**, which in turn causes the ratchet pawl **64d** to engage with the ratchet gear **64c**, thereby stopping the paying out of the seat belt from the takeup shaft **64a**. A hydraulic or pneumatic cylinder may be used instead of the solenoid coil **69**.

The above-described takeup mechanism corresponds to the seat belt **21** for the waist provided on the left-hand side in FIG. **8**, and an identical takeup mechanism corresponding to the seat belt **21** for the waist provided on the right-hand side is provided on the right-hand side of the mechanism.

Another takeup mechanism, which is identical with the one described above and comprises the retractor **64**, the support member **67**, the solenoid coil **69**, and the like, is provided underneath the central portion of the underside of

the seat, as shown in FIG. 5. The seat belts for shoulders, after being passed through the belt holes 19, are connected to this takeup mechanism.

A bracket 71 whose transverse sides are made open is mounted on a central portion of the mounting base, and a square opening 72 is provided in a central portion to an upper plate of the bracket 71. A bumper member 73 is secured to the right-hand side of the square opening 72. The tightening mechanism is arranged such that two rollers 75a, 75b having substantially the same size as the aforementioned turn roller 65 are arranged parallel with each other and are rotatably supported by two elongated plates 76 at their opposite ends. Each of a pair of support shaft 76a is provided on a central portion of the outer side of each elongated plate 76 in parallel with the rollers 75a, 75b. One roller 75a projects upwardly from the square opening 72 provided in the upper plate of the bracket, and a support shaft of the roller 75a is connected at its opposite ends to the horizontal rods 61 via rod ends 77 disposed outside the upper ends of the elongated plates 76.

The seat belt 21 for the waist disposed on the right-hand side of the occupant (the left-hand coat belt 21 in FIG. 8) is paid out from the left-hand retractor 64, as viewed in the drawing, and is passed around the turn roller 65, the lower roller 75b of the tightening mechanism 74, and the turn roller 78 located on the right-hand side of the seat belt tightening lever 25 as viewed in the drawing. This seat belt 21 is then passed through the belt hole 24 and is sewn onto the tongue 22. Similarly, the seat belt 21 for the waist disposed on the left-hand side of the occupant (the right-hand aide seat belt 21 in FIG. 8) is paid out from the right-hand retractor 64, as viewed in the drawing, and is passed around the turn roller 65, the upper roller 75a of the tightening mechanism 74, and the turn roller 78 shown at upper right in FIG. 8. This seat belt 21 is then passed through the belt hole 24 and is sewn onto the tongue 22.

Although in the above-described embodiment the operation of tho neat belt tightening lever is transmitted to the belt tightening mechanism via the bell crank, it is apparent that the operation of the sabt belt tightening lever may be transmitted to the seat belt tightening mechanism by adopting a clad wire used in a brake for a bicycle and the like.

In operation, after the occupant or the player is seated in a cockpit portion of the rotating recreational machine, he or she lowers the breast holding arms ad fits them to his or her body. At that time, the seat belts for shoulders are applied to his or her breast by being paid out behind the back of the seat, around the auxiliary shaft, through the belt holes provided in the back of the seat, and around the occupant's back. As the breast holding arms are lowered, the auxiliary shaft is raised upwardly, which causes the seat belts for shoulders to be paid out from the retractor provided on the underside of the seat, and a pulling force of a fixed strength by means of the resilient force of the spiral spring of the retractor is applied to the seat belts for shoulders. Hence, the occupant is capable of wearing the seat belts for shoulders in conformity with his or her shoulders and without free play around his or her shoulders.

When the position of the breast holding arms is determined, the left and right seat belts for the waist are pulled and are locked by the buckle lock mechanism. Then, if the belt tightening lever provided on a side of the seat is pulled upwardly, the connecting rod connected to the belt tightening lever pulls up the bell crank counterclockwise. The two horizontal rods connected to the bell crank rotate the tightening mechanism counterclockwise, which in turn causes the rollers mounted on the tightening mechanism to move counterclockwise, as shown in a front elevational view of the coat belt tightening mechanism in FIG. 9. Hence, it is possible to increase the distance of the seat belt between tho turn roller provided on the mounting base and the turn roller provided by the Bide of the seat. The seat belts for the waist are thus tightened until they fit the occupant's waist.

When the occupant completes the above-described operation and presses a start button (not shown) for starting the rotating recreational machine, driving portions such as a solenoid coil of each seat belt takeup mechanism are reset, the rectangular member which has retained the ratchet pawl of each retractor causes the ratchet pawl to engage with the ratchet gear by means of the action of the tensile spring. As a result, the takeup shaft to which the ratchet gear is secured does not pay out the seat belt any longer and is fixed at that position. In addition, the driving portions such as the solenoid coil and the like of the buckle lock mechanism are also reset, and the movable plate such as the disk is returned in the opposite direction by means of the action of a tensile spring, which makes it impossible to press down the pushbutton, thereby making it impossible to remove the tongues.

Accordingly, when the occupant is seated in the seat and causes the breast holding arms to abut against his or her body, his or her weight can be supported by the breast holding arm even if tho seat moves vertically. In addition, it is possible to prevent the occupant's body from moving upwardly by means of the seat belts for shoulders, and fix the occupant's waist to the seat by means of the left and right seat belts for the waist, thereby preventing the occupant's body from being moving from the seat. Furthermore, the buckle lock mechanism ensures that, after the seat belts for the waist are worn, the occupant him- or herself cannot remove the seat belts until safety is guaranteed, thereby maintaining safety.

What is claimed is:

1. In a simulator game machine having an occupant holding apparatus and means for providing images to the occupant, the improvement comprising:

- a seat member positioned to enable the occupant to see the images;
- means for moving the seat member in coordination with the images; and
- means for securing the occupant to the seat member including:
  - a rotating breast holding arm member that rotates to a first position across the front of the occupant for retention and rotates away from the occupant to a second position for release of the occupant;
  - a lock mechanism positioned on the breast holding arm member;
  - a pair of seat belts, one on either side of the seat member, the seat belts being configured for removable retention to the lock mechanism when the breast holding arm member is in the first position; and
  - means for locking the seat belts to prevent the occupant from releasing the seat belts during activation of the means for moving.

2. A simulator game machine as in claim 1 further including a pair of shoulder seat belts attached to the rotating breast holding arm member for engaging shoulders of the occupant when the rotating breast holding arm member is in the first position and means for adjusting the shoulder seat belts to securely engage the occupant's shoulders.

3. A simulator game machine as in claim 2 wherein the means for adjusting the shoulder seat belts includes an

auxiliary shaft member that is mounted on the rotating breast holding arm member and moves the shoulder seat belts from a secure engagement of the shoulders in the first position to a disengagement of the shoulders in the second position.

4. A simulator game machine as in claim 1 including means for biasing the breast holding arm member to one of the first position and the second position as it rotates between these positions.

5. A simulator game machine as in claim 4 wherein the means for biasing includes an overcenter mounted spring member that is connected to the breast holding arm member.

6. A simulator game machine as in claim 1 further including a manual lever and means for tightening the seat belts when the manual lever is moved by the occupant.

7. A simulator game machine as in claim 1 further including a manual button member mounted on the lock mechanism for releasing the seat belts, wherein the means for locking includes a solenoid member and a disk member that is moved by the solenoid member to engage or disengage the operation of the button member whereby the occupant cannot release the seat belts during activation of the means for moving.

8. A simulator game machine as in claim 1 further including means for detecting the insertion of the seat belts in the lock mechanism to thereby enable the means for locking.

9. A simulator game machine as in claim 1 wherein the rotating breast holding arm member is pivotally mounted above and behind the seat member to rotate over the occupant.

* * * * *

May 8, 1951 K. E. DUNBAR 2,552,002

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Fig. 1.

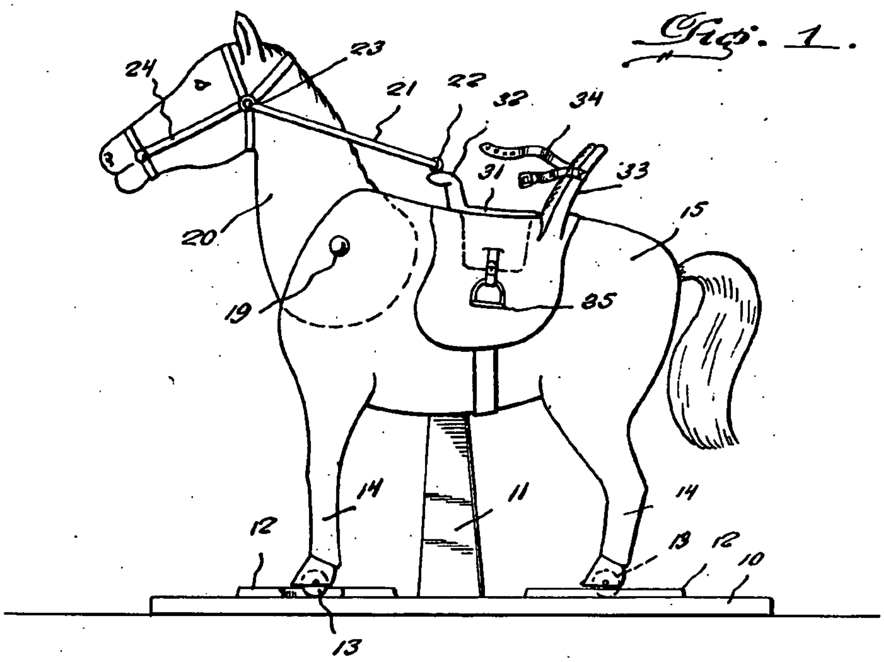

Fig. 2.

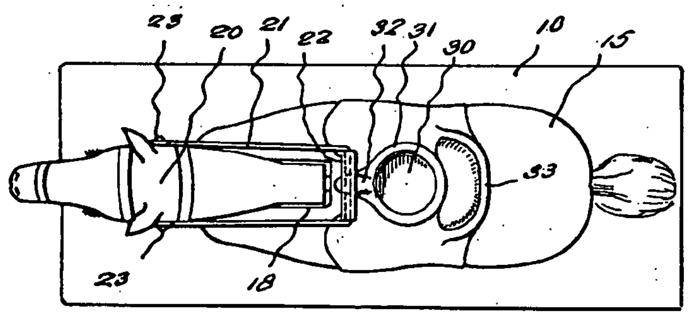

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Fig. 3.

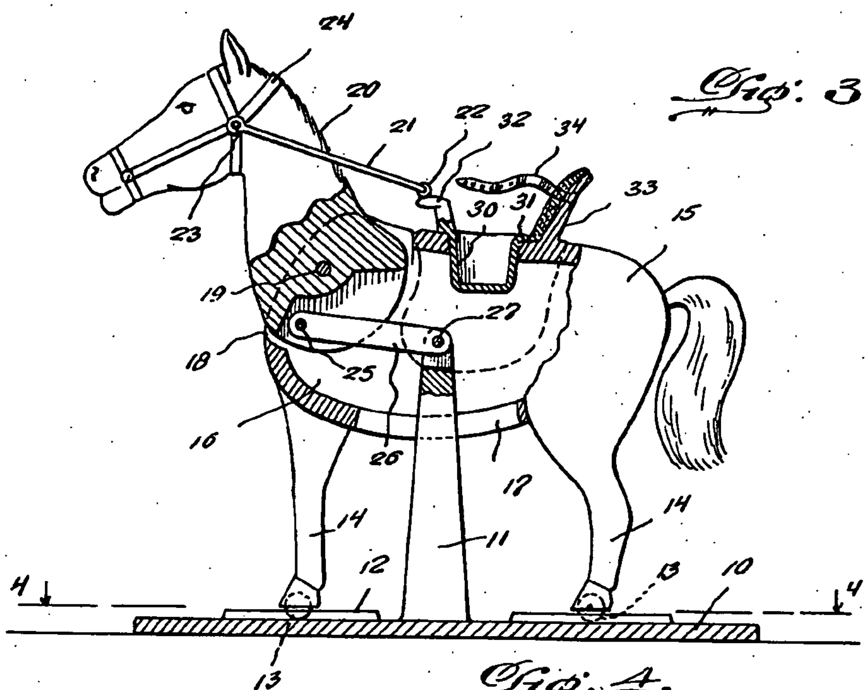


Fig. 4.

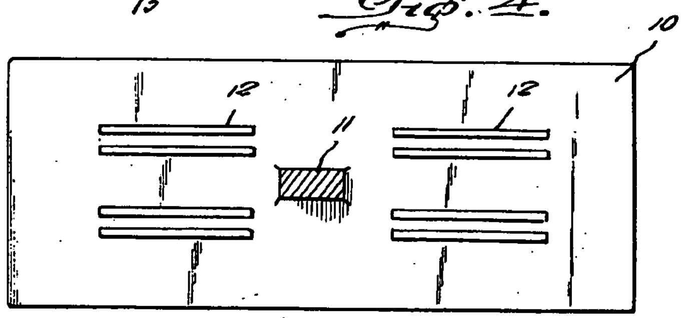
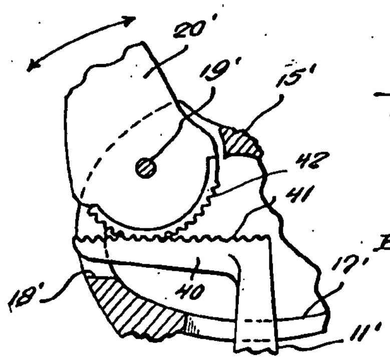


Fig. 5.



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4 Claims. (Cl. 272—53.1)

1

This invention relates to an amusement and training device for children, and more particularly to a device for training a small child to utilize a commode.

A primary object of this invention is the provision of a device adapted for the amusement and entertainment of a small child while seated upon a commode for the performance of natural functions, thus lessening the tedium of waiting and holding the child's interest until such functions have been performed.

An additional object of the invention is the provision of such a device characterized by mobility, whereby the normal bodily motion of a small child while seated upon a commode is translated into motion of the apparatus, to the edification of the child, thus holding his interest.

As conducive to a clearer understanding of this invention, it may here be pointed out that in training a small child to utilize the commode, the child, when seated thereon, frequently becomes restless, and by bodily movement not infrequently upsets the device, or falls, or creates other difficulties. An object of this invention, therefore, is the provision of a device whereby, when the child is compelled to remain in such a situation for a relatively long period of time, such bodily motion may be accommodated without harmful consequences, and further, by impartation of movement to the device will amuse and hold the interest of the child.

A still further object of the invention is the provision of such a device which will be sturdy and durable in construction, reliable and efficient in operation, and relatively simple to construct, empty and clean.

Other objects will in part be obvious and in part be pointed out as the description of the invention proceeds, and shown in the accompanying drawings, wherein there is disclosed a preferred embodiment of this inventive concept.

In the drawings:

Figure 1 is a side elevational view of one form of the device embodying this inventive concept, certain concealed portions thereof being indicated in dotted lines.

Figure 2 is a top plan view of the device disclosed in Figure 1.

Figure 3 is a side view partially in section and partially in elevation of the device disclosed in Figure 1.

Figure 4 is a sectional view taken substantially along the line 4—4 of Figure 3.

Figure 5 is an enlarged fragmentary sectional view of a modified form of a constructional detail.

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Similar reference characters refer to similar parts throughout the several views of the drawings.

Having reference now to the drawings, the device is comprised of a base 10, provided with a centrally positioned fixed supporting post 11, and having spaced parallel guide rails 12, as best shown in Figure 4, providing guide channels for rollers 13 rotatably mounted at the extremities of legs 14 of a body portion 15, which may be in simulation of a horse, or any other desired animal, or the like. As best shown in Figure 3, the body portion 15 is hollow and provided with a central recess 16, and an elongated slot 17 in the lower portion thereof, through which the supporting post 11 extends, in such manner that linear or longitudinal movement of the body within the channels 12, is permitted with respect to the post 11, such motion being accomplished in a manner to be more fully described hereinafter.

The forward extremity of the body portion 15 is provided with a slotted aperture 18, within which is pivotally mounted, as on a pivot 19, a portion 20 in simulation of a horse's head and neck.

The portion 20 is provided with relatively rigid rods 21 terminating in a handle portion 22, and secured, as at 23, to the bridle 24 of the horse, the arrangement being such that pressure exerted on the handle 22 results in pivotal movement of the head portion 20 about the pivot 19.

The lower portion of the member 20 is pivoted, as on a pivot 25, below the pivot 19 to a link 26, the opposite end of which is pivoted, as on a pivot 27, to the upper extremity of the post 11. Thus, it will be seen that pressure on the handle 22 imparting motion about the pivot point 19 to the member 20 results through the linkage above described in linear movement of the body 15 within the guideways 12.

In the portion of the body normally occupied by a saddle, there is provided an aperture of circular or oval or other desired shape, within which is adapted to be positioned a commode 30 provided with a flange or rim 31 for supporting the same in the aperture, and having a handle 32 formed in simulation of a saddle horn. A back 33 may be provided affixed to the body to afford a rest for the child positioned on the animal, and straps 34 may also be provided for securing the child against an accidental fall. If desired, stirrups 35 may also be provided (see Fig. 1).

If desired, the aperture may be closed by a suitable cover (not shown) in order that the device may be used as a toy alone.

From the foregoing the operation of the device should be readily apparent. When it is desired to have the child attend to a call of nature, he is positioned upon the commode 30 as though astride a horse, or other animal, and secured in position, as by means of the straps 34. Obviously, if the child grasps the handle 22 and pushes or pulls thereupon, the head portion 20 will be caused to move about the pivot 19, thus resulting in a reciprocatory movement of the body 15, to the edification and amusement of the child, and in such manner as to hold his interest for the requisite period of time.

A modified form of construction is disclosed in Figure 5, wherein there is disclosed a body 15' provided with a slot 18', into which extends the extremity of a head portion 20' pivoted, as on a pivot 19'. A post 11' extends upwardly into the body portion through a suitable slot 17'.

In this modification, however, the post 11' is provided with an extending portion 40 which extends forwardly into the slot 18' and is provided on its upper surface with a rack 41 comprised of a plurality of teeth. The lower portion of the member 20' is arcuate in configuration, and is provided with a toothed segment 42 adapted to engage with the rack 41. Obviously, in this modification, movement of the portion 20' in either direction will, through engagement with the rack, cause a movement of the body portion 15' similar to that previously discussed in the foregoing modification.

From the foregoing it will now be seen that there is herein provided a device accomplishing all the objects of this invention, and others, including many advantages of great practical utility and commercial importance.

As many embodiments may be made of this inventive concept, and as many modifications may be made in the embodiment hereinbefore shown and described, it is to be understood that all matter herein is to be interpreted merely as illustrative and not in a limiting sense.

I claim:

1. A movable support comprising a hollow body having an elongated recess in one end, and an elongated recess in the lower side thereof, means on said body providing a seat and a seat back, and four supporting legs depending from said body, a supporting base beneath said legs, respective guideways on said base for the lower ends of said legs, a post secured to said base and extending upwardly through said recess in the lower side of said body, a movable member having one end portion extending through said recess in one end of said body, a pivotal connection between said movable member and said body, a link pivotally connected at one end to the upper end of said post and at its opposite end to said movable member at a location spaced from said pivotal connection whereby movement of said member about said pivotal connection imparts translatory movement of said body and legs relative to said base, a pair of rods pivotally connected at corresponding ends to said movable member at a location spaced from said pivotal connection between said movable member and said body, and a handle connected to the opposite ends of said rods and disposed adjacent said seat.

2. A movable support comprising a hollow body simulating an animal body, a base, guideways on said base, wheels on said body supporting said body on said guideways for movement relative to said base, and means for moving said body relative to said base comprising an animal head simulating member pivotally mounted on said body, a post extending from said base into said hollow body, means connecting said head member to the upper end of said post, and occupant-operated means connected to said head member for imparting pivotal movement to the latter relative to said body.

3. A movable support comprising a hollow body simulating an animal body, a base, guideways on said base, wheels on said body supporting said body on said guideways for movement relative to said base, and means for moving said body relative to said base comprising an animal head simulating member pivotally mounted on said body, a post extending from said base into said hollow body, means connecting said head member to the upper end of said post, and occupant-operated means connected to said head member for imparting pivotal movement to the latter relative to said body, said means connecting said head member to said post comprising a link pivotally connected at one end to said head member at a location spaced from the pivotal connection between said head member and said body, and a pivotal connection between the opposite end of said link and said post.

4. A movable support comprising a hollow body simulating an animal body, a base, guideways on said base, wheels on said body supporting said body on said guideways for movement relative to said base, and means for moving said body relative to said base comprising an animal head simulating member pivotally mounted on said body, a post extending from said base into said hollow body, means connecting said head member to the upper end of said post, and occupant-operated means connected to said head member for imparting pivotal movement to the latter relative to said body, said means connecting said head member to said post comprising a gear sector on said head member adjacent the pivotal connection between said head member and said body, and a rack on said post having teeth in mesh with the teeth of said gear sector.

KARL E. DUNBAR.

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Number	Country	Date
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US006007338A

United States Patent [19]

DiNunzio et al.

[11] **Patent Number: 6,007,338**

[45] **Date of Patent: Dec. 28, 1999**

[54] **ROLLER COASTER SIMULATOR**

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[73] Assignee: **Disney Enterprises, Inc.**, Del.

[21] Appl. No.: **08/971,308**

[22] Filed: **Nov. 17, 1997**

[51] **Int. Cl.⁶** **A63G 31/00**

[52] **U.S. Cl.** .... **434/55**; 434/29; 434/307 R; 434/365; 472/43; 472/59; 345/302; 345/121; 463/31

[58] **Field of Search** .... 434/29, 30, 34, 434/35, 37, 38, 40, 43, 45, 55, 58, 59, 62, 69, 118, 307 R, 308, 365, 372; 472/2, 17, 43, 47, 59, 60, 64, 132, 135; 482/1–9, 900–903; 463/2, 31, 34, 40, 46; 104/53, 85, 154; 348/15, 121, 124, 578; 345/302, 473, 121, 326, 328, 145, 161, 163, 167, 173, 425, 949, 952, 971, 978

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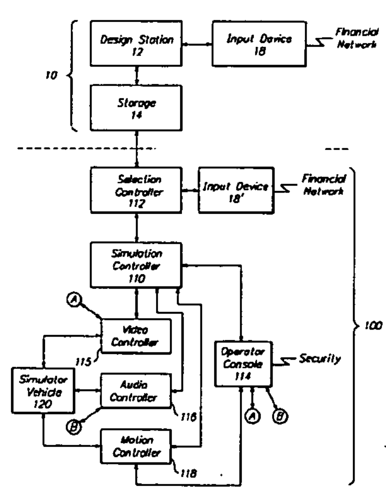
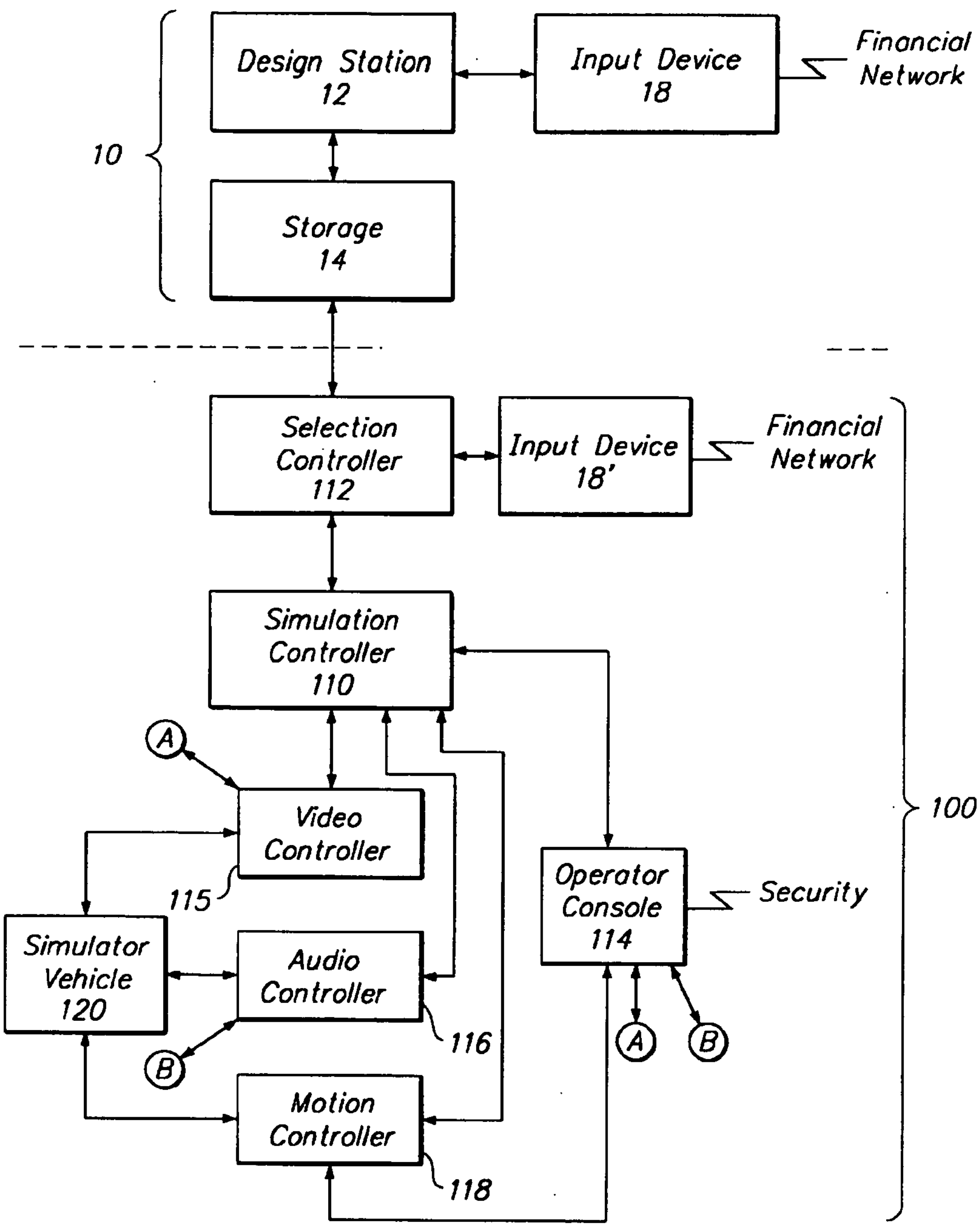
Primary Examiner—Joe H. Cheng
Attorney, Agent, or Firm—Medlen & Carroll, LLP

[57] **ABSTRACT**

A realistic roller coaster simulator is disclosed having one or more passenger seats equipped with a safety harness and mounted for 360 degree rotational movement along at least two axes for simulating the motion of a roller coaster. A controller is provided for controlling and coordinating the motion of the simulator with a simulation controller which generates to the passenger synchronized audio and visual effects which would be experienced by a passenger on a roller coaster of a predetermined design. Linked to the simulator is a design station where a passenger can design his or her own roller coaster. Upon entering the simulator station, the passenger's design can be accessed from memory and selected for simulation on the simulator vehicle. Upon initiation of the simulation, the passenger can experience in real time the visual, motive, audible and other effects (such as wind, heat, cold, water, etc.) of the simulated roller coaster ride which the passenger has designed.

39 Claims, 11 Drawing Sheets





Design Station 12
Input Device 18
Financial Network
10
Storage 14
Selection Controller 112
Input Device 18'
Financial Network
Simulation Controller 110
A
Video Controller
115
100
Operator Console 114
Security
Simulator Vehicle 120
Audio Controller
116
B
A
B
Motion Controller
118

FIG. 1

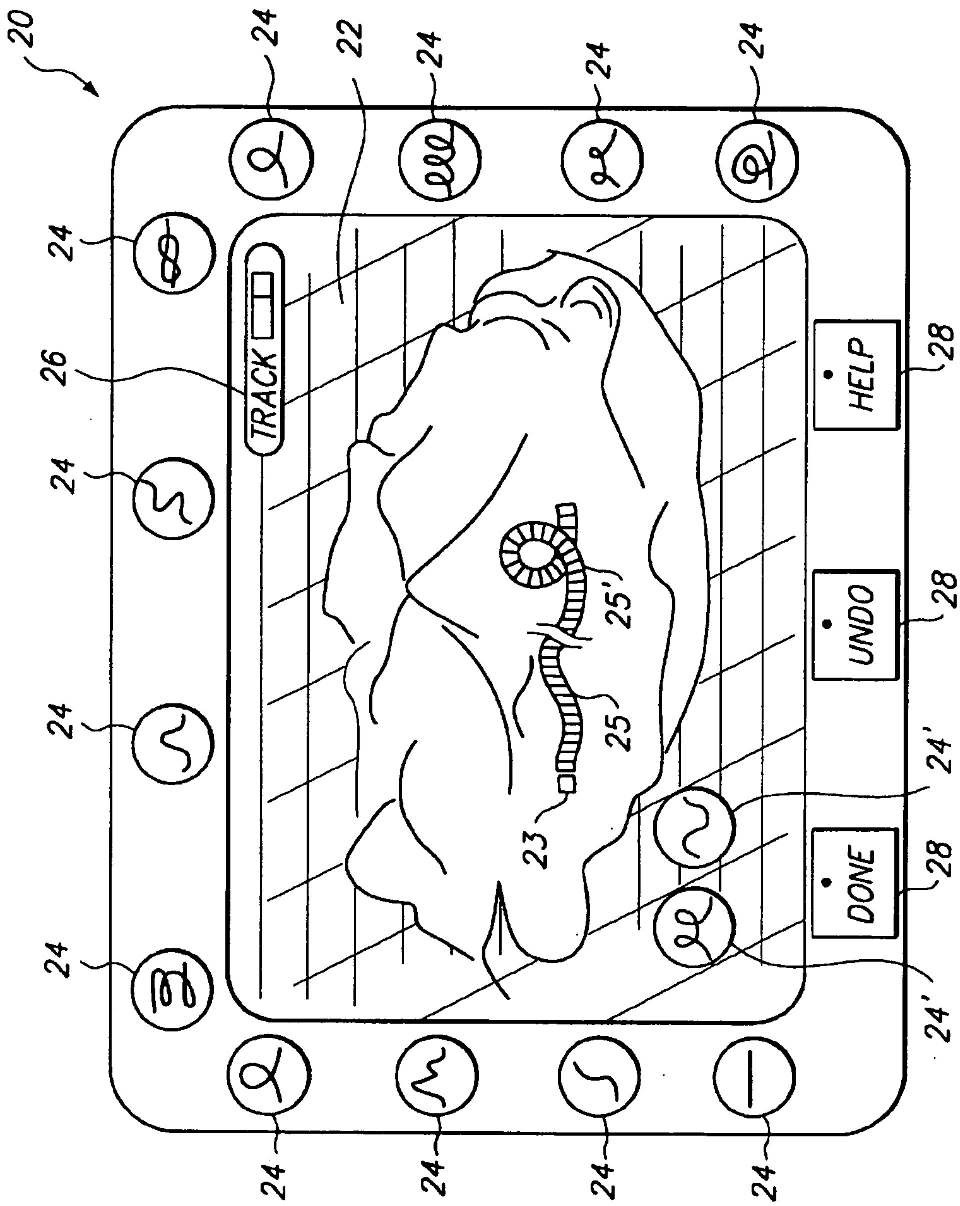


FIG. 2

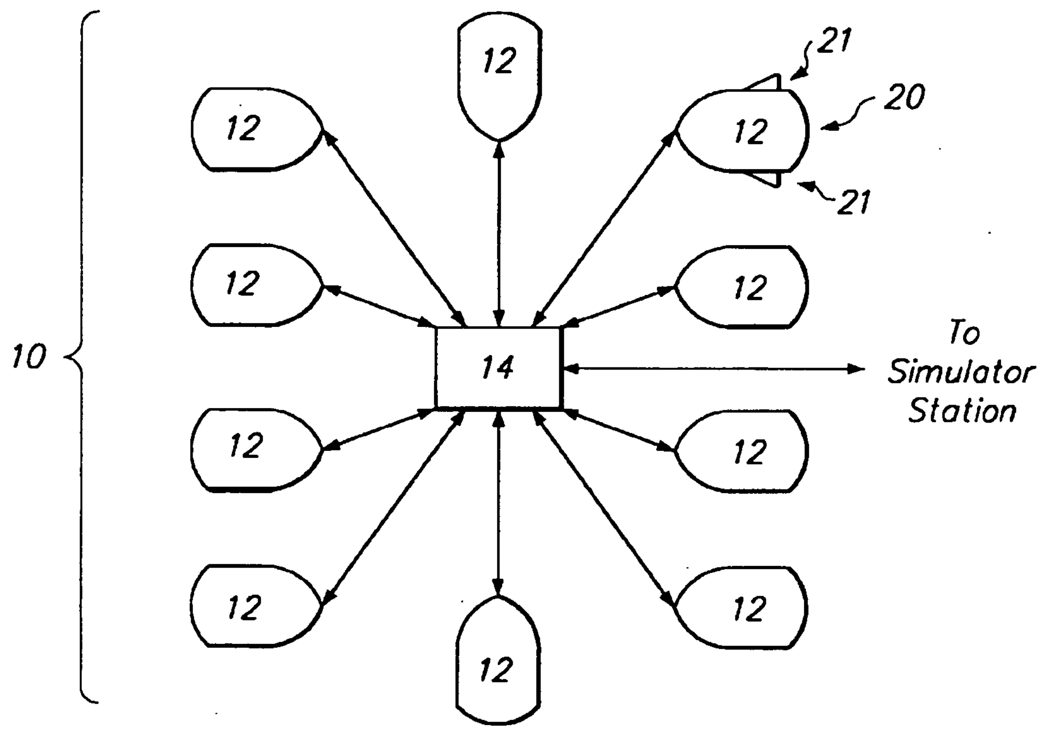
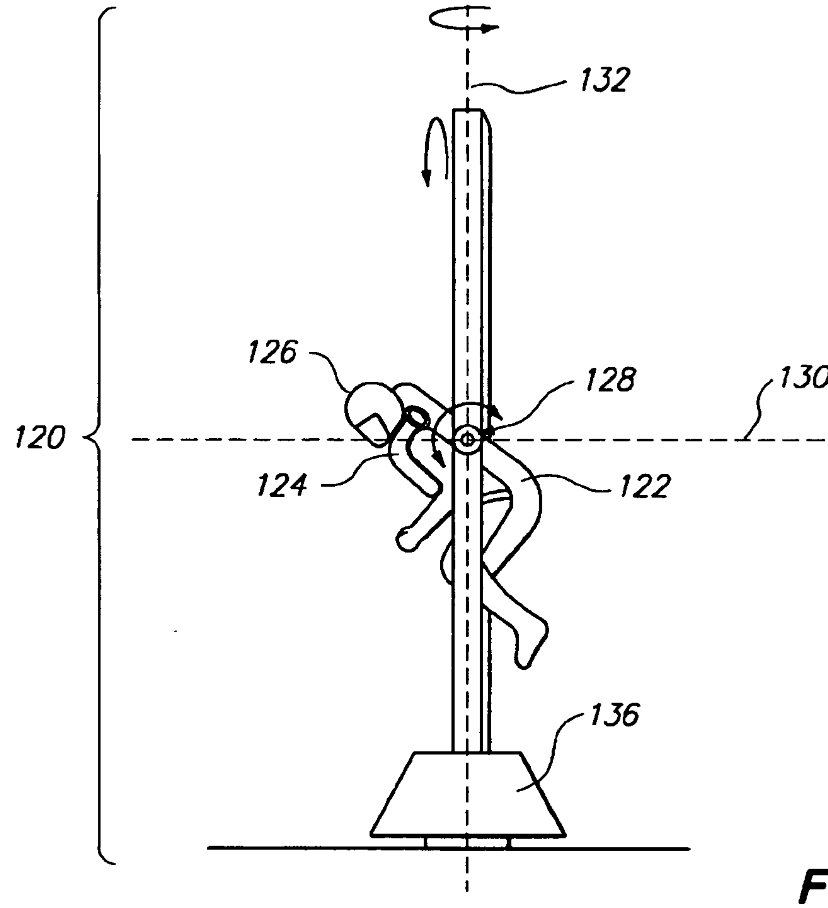


FIG. 3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126
128
130
120
124
122
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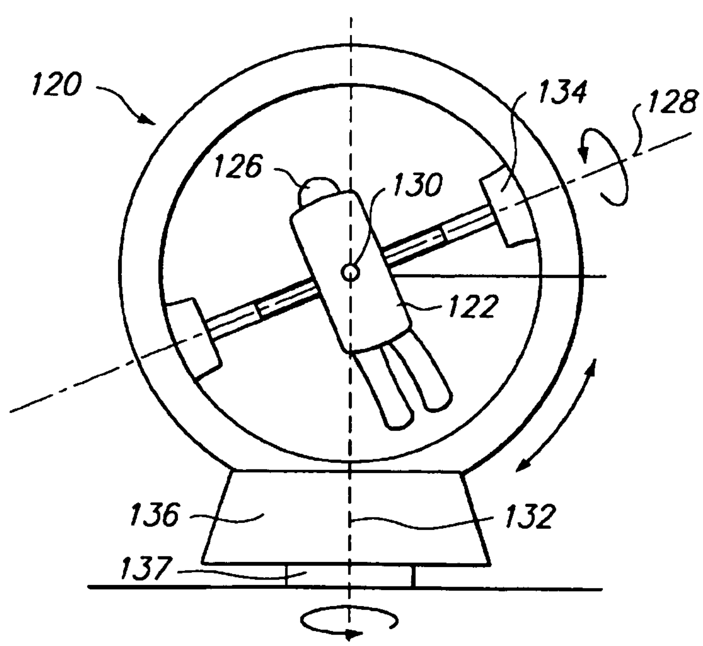
FIG. 4A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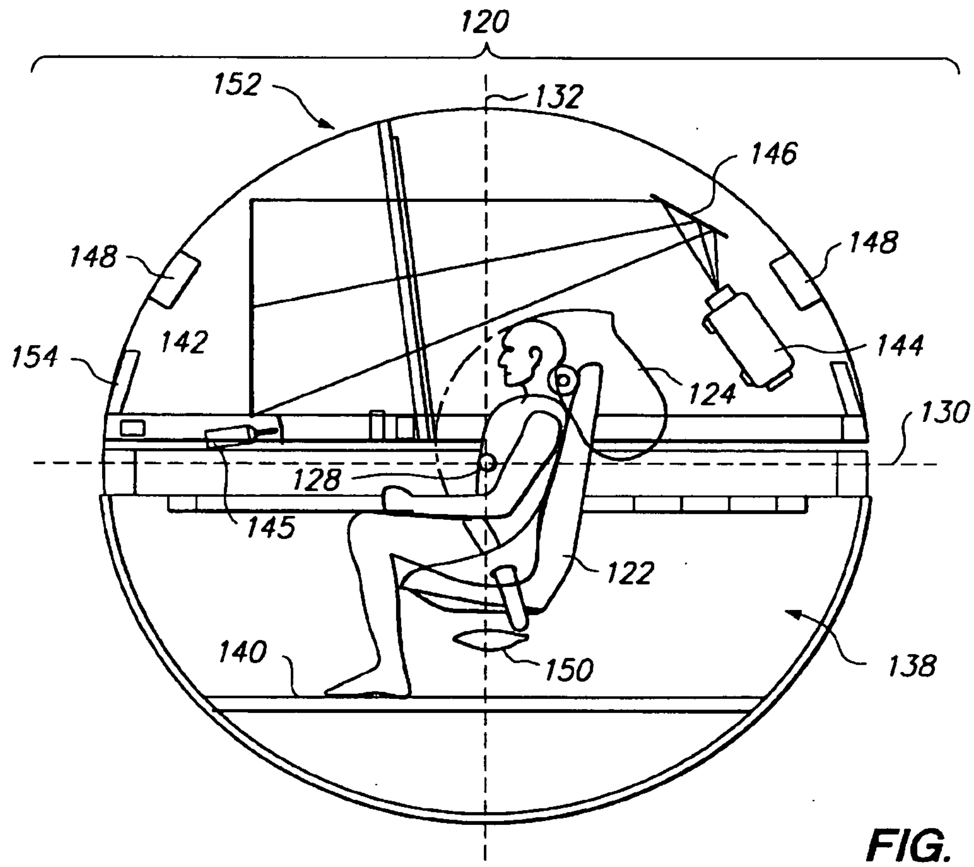
132
137

FIG. 4B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152
132
146
148
148
142
154
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124
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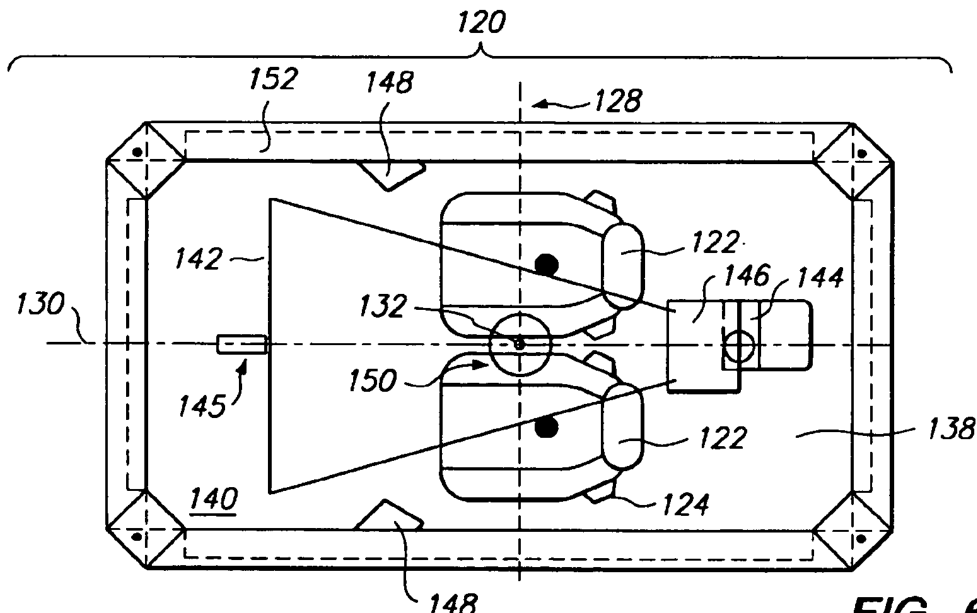
128
145
122
140
150
138

FIG. 5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152
148
128
142
122
146
144
130
132
145
150
122
138
140
124
148

FIG. 6

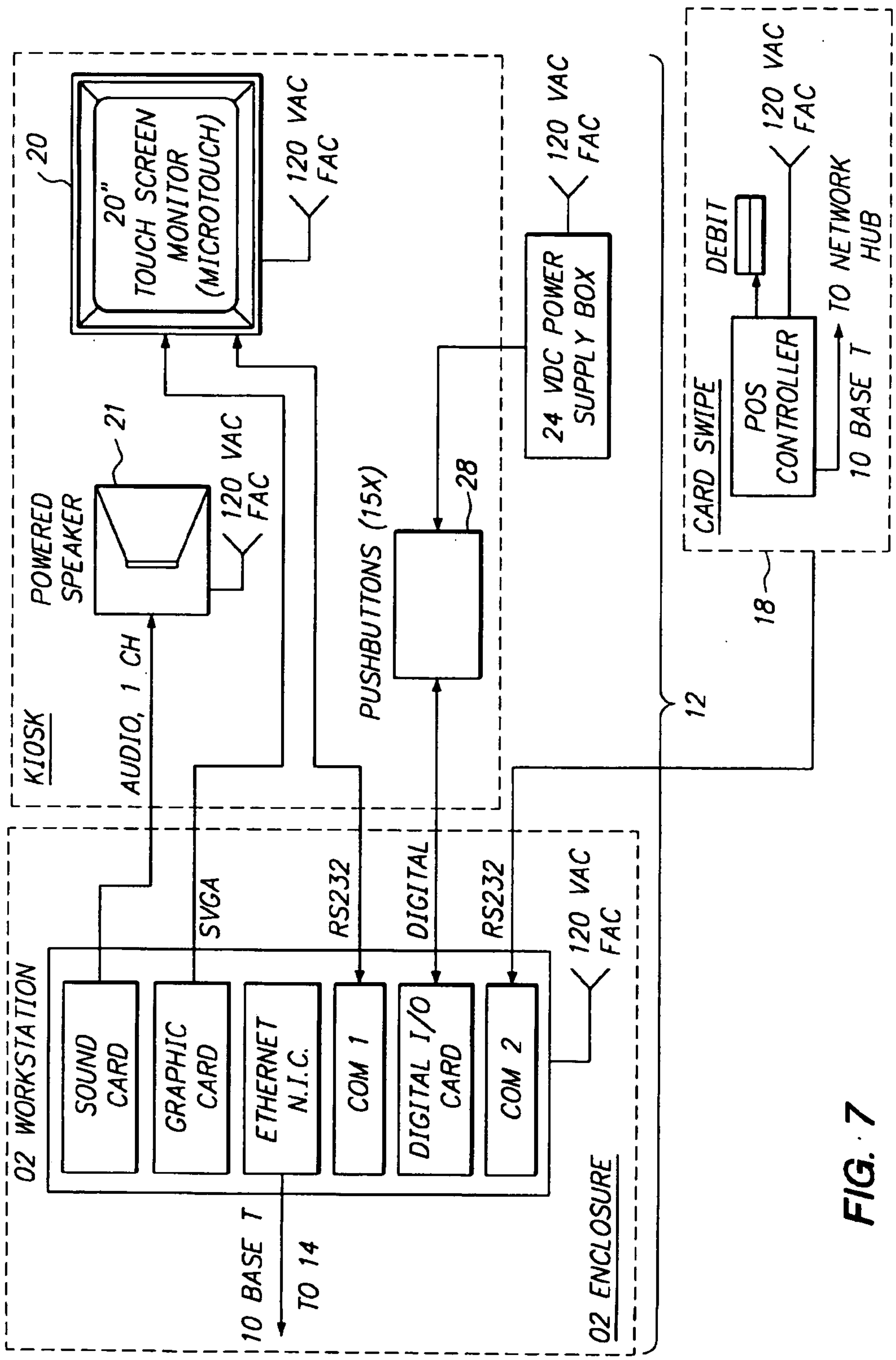

KIOSK
20
20" TOUCH SCREEN MONITOR (MICROTOUCH)
120 VAC FAC
21
POWERED SPEAKER
120 VAC FAC
AUDIO, 1 CH
28
PUSHBUTTONS (15X)
24 VDC POWER SUPPLY BOX
120 VAC FAC
12
CARD SWIPE
DEBIT
POS CONTROLLER
120 VAC FAC
TO NETWORK HUB
10 BASE T
18
02 WORKSTATION
SOUND CARD
GRAPHIC CARD
ETHERNET N.I.C.
COM 1
DIGITAL I/O CARD
COM 2
SVGA
RS232
DIGITAL
RS232
120 VAC FAC
10 BASE T
TO 14
02 ENCLOSURE

FIG. 7

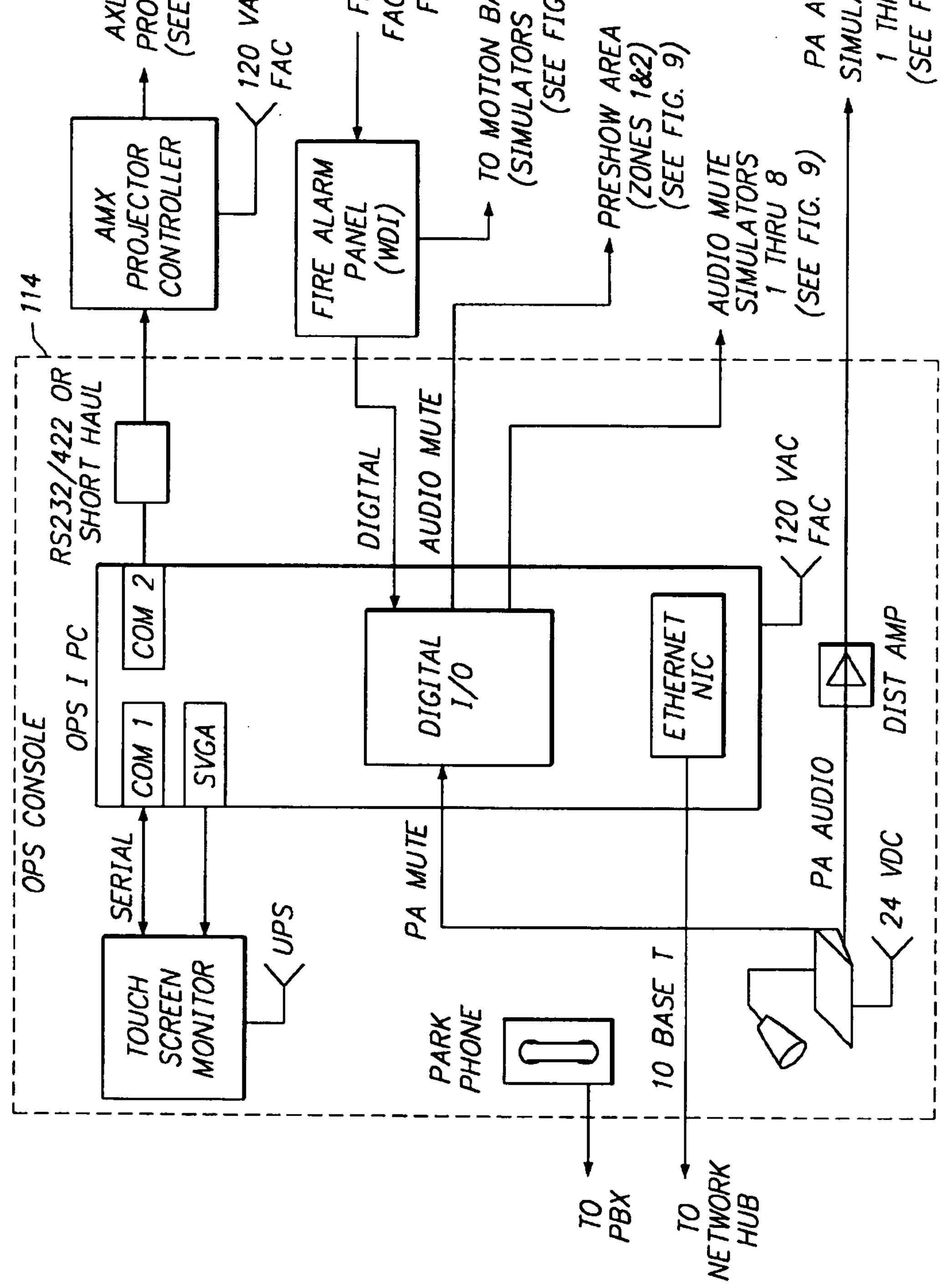

114
OPS CONSOLE
OPS I PC
COM 1
COM 2
SVGA
DIGITAL I/O
ETHERNET NIC
DIST AMP
TOUCH SCREEN MONITOR
UPS
SERIAL
RS232/422 OR SHORT HAUL
AMX PROJECTOR CONTROLLER
120 VAC FAC
AXLINK TO PROJECTORS (SEE FIG. 9)
FIRE ALARM PANEL (WDI)
FROM FACILITY FACP
TO MOTION BASE PC104 (SIMULATORS 1 THRU 8) (SEE FIG. 10)
PRESHOW AREA (ZONES 1&2) (SEE FIG. 9)
AUDIO MUTE SIMULATORS 1 THRU 8 (SEE FIG. 9)
PA AUDIO SIMULATORS 1 THRU 8 (SEE FIG. 9)
DIGITAL
AUDIO MUTE
120 VAC FAC
PA MUTE
PA AUDIO
24 VDC
PARK PHONE
10 BASE T
TO PBX
TO NETWORK HUB
FIG. 8

FIG. 9A

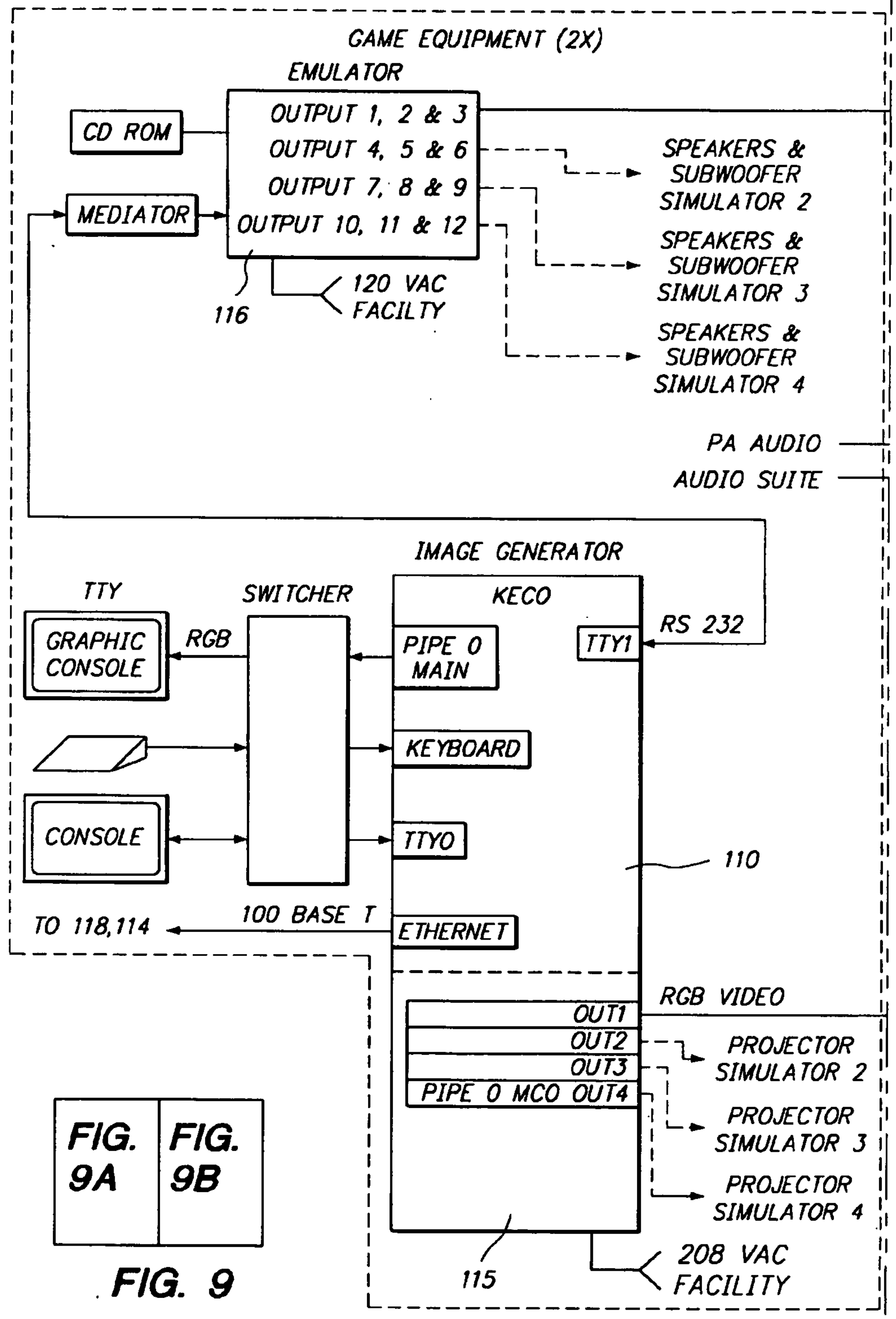
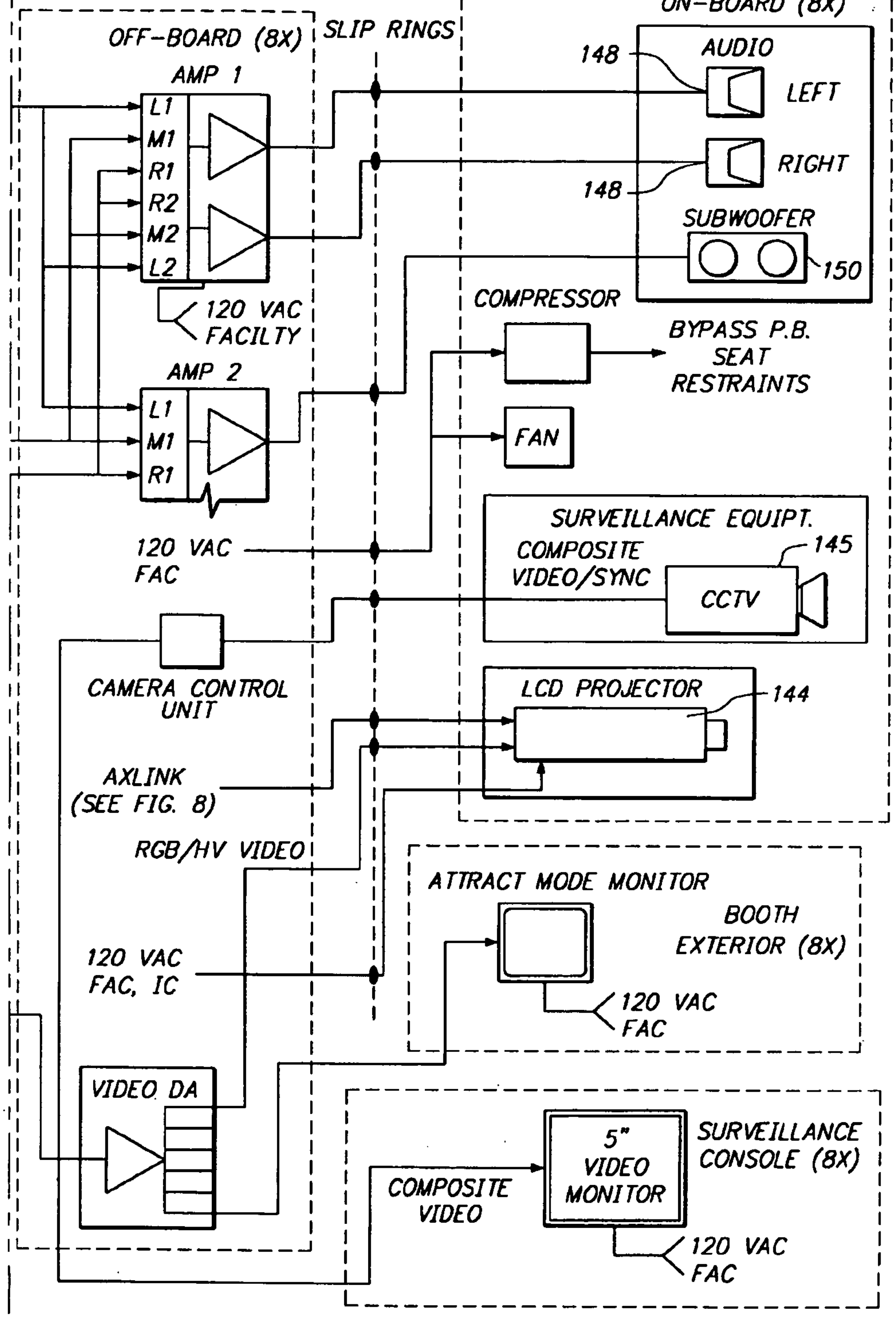

SIMULATOR BOOTH
GAME EQUIPMENT (2X)
EMULATOR
CD ROM
MEDIATOR
OUTPUT 1, 2 & 3
OUTPUT 4, 5 & 6
OUTPUT 7, 8 & 9
OUTPUT 10, 11 & 12
SPEAKERS & SUBWOOFER SIMULATOR 2
SPEAKERS & SUBWOOFER SIMULATOR 3
SPEAKERS & SUBWOOFER SIMULATOR 4
116
120 VAC FACILTY
PA AUDIO
AUDIO SUITE
IMAGE GENERATOR
KECO
TTY
SWITCHER
GRAPHIC CONSOLE
RGB
PIPE 0 MAIN
TTY1
RS 232
KEYBOARD
CONSOLE
TTYO
110
TO 118,114
100 BASE T
ETHERNET
RGB VIDEO
OUT1
OUT2
OUT3
PIPE 0 MCO OUT4
PROJECTOR SIMULATOR 2
PROJECTOR SIMULATOR 3
PROJECTOR SIMULATOR 4
115
208 VAC FACILITY
FIG. 9A
FIG. 9B

FIG. 9

FIG. 9B


OFF-BOARD (8X)
SLIP RINGS
ON-BOARD (8X)
AMP 1
L1
M1
R1
R2
M2
L2
120 VAC FACILTY
AMP 2
L1
M1
R1
120 VAC FAC
148
AUDIO
LEFT
RIGHT
148
SUBWOOFER
150
COMPRESSOR
BYPASS P.B. SEAT RESTRAINTS
FAN
SURVEILLANCE EQUIPT.
COMPOSITE VIDEO/SYNC
145
CCTV
CAMERA CONTROL UNIT
LCD PROJECTOR
144
AXLINK (SEE FIG. 8)
RGB/HV VIDEO
120 VAC FAC, IC
ATTRACT MODE MONITOR
BOOTH EXTERIOR (8X)
120 VAC FAC
VIDEO DA
5" VIDEO MONITOR
SURVEILLANCE CONSOLE (8X)
COMPOSITE VIDEO
120 VAC FAC

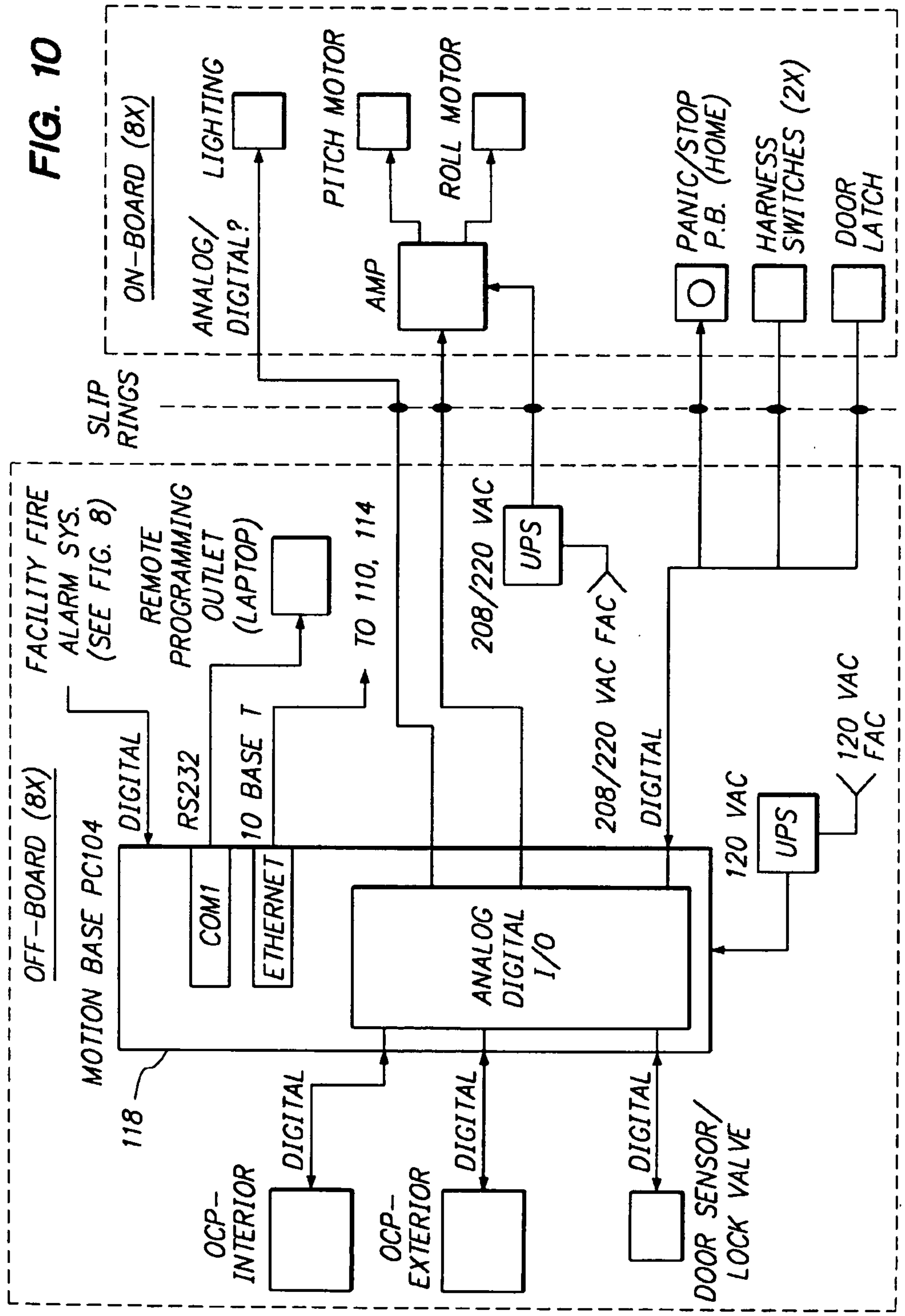

ON-BOARD (8X)
ANALOG/
DIGITAL?
LIGHTING
PITCH MOTOR
ROLL MOTOR
AMP
PANIC/STOP
P.B. (HOME)
HARNESS
SWITCHES (2X)
DOOR
LATCH
SLIP
RINGS
OFF-BOARD (8X)
MOTION BASE PC104
118
FACILITY FIRE
ALARM SYS.
(SEE FIG. 8)
REMOTE
PROGRAMMING
OUTLET
(LAPTOP)
TO 110, 114
208/220 VAC
UPS
208/220 VAC FAC
DIGITAL
RS232
10 BASE T
208/220 VAC
DIGITAL
120 VAC
UPS
120 VAC
FAC
COM1
ETHERNET
ANALOG
DIGITAL
I/O
DIGITAL
DIGITAL
DIGITAL
OCP-
INTERIOR
OCP-
EXTERIOR
DOOR SENSOR/
LOCK VALVE

FIG. 10

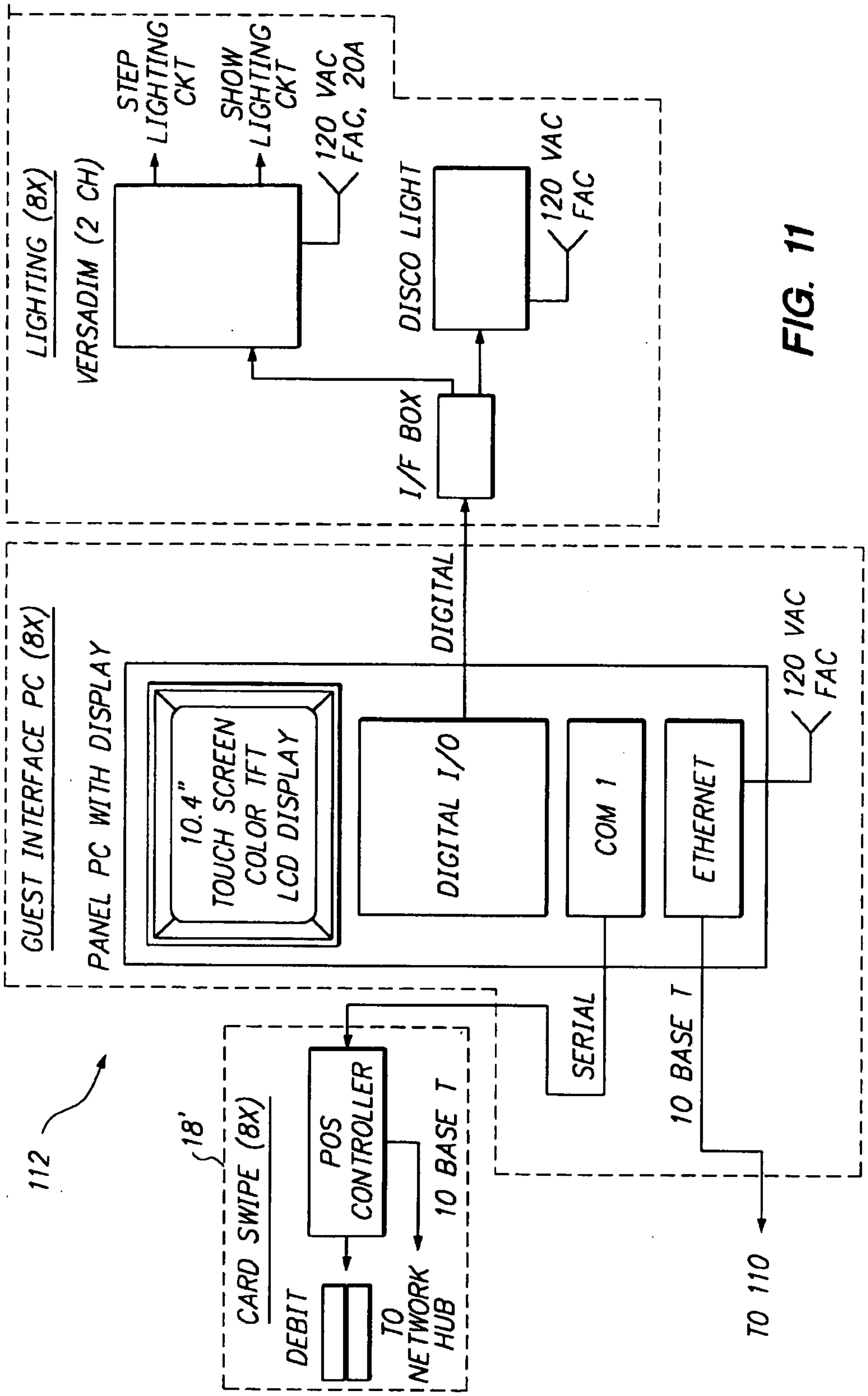

LIGHTING (8X)
VERSADIM (2 CH)
STEP LIGHTING CKT
SHOW LIGHTING CKT
120 VAC FAC, 20A
DISCO LIGHT
120 VAC FAC
I/F BOX
DIGITAL
GUEST INTERFACE PC (8X)
PANEL PC WITH DISPLAY
10.4" TOUCH SCREEN COLOR TFT LCD DISPLAY
DIGITAL I/O
COM 1
ETHERNET
120 VAC FAC
SERIAL
10 BASE T
TO 110
112
18'
CARD SWIPE (8X)
POS CONTROLLER
10 BASE T
DEBIT
TO NETWORK HUB

FIG. 11

ROLLER COASTER SIMULATOR

FIELD OF THE INVENTION

The present invention relates to the field of amusement rides; more particularly, the present invention relates to ride simulators.

BACKGROUND OF THE INVENTION

Traditional roller coasters achieve thrill by using low speed lift hills, steep drops, 360 degree loops, and high-speed turns. In an effort to attract enthusiasts, theme parks invest significant sums for newer and more thrilling roller coasters which add additional and different effects. However, traditional roller coasters are inefficient. Tall lift hills and the length of track required for high speed runout disrupt the aesthetics of a themed environment and consume valuable real estate.

Furthermore, in the event of a failure or malfunction of equipment, there is an element of danger to passengers traveling at the speeds and from the heights normally encountered in conventional roller coasters. Finally, since the coaster vehicles typically traverse the same track time after time, riders quickly become bored with a particular ride.

The significant cost of roller coasters, in terms of equipment and real estate, has only recently been addressed by simulators which are capable of generating roller coaster effects in an amusement ride which takes up very little space. Such simulators are typically much safer than traditional roller coasters, since the passengers are never more than a few feet above the floor. For example, U.S. Pat. Nos. 5,507,647 and 5,388,991 describe simulator vehicles which can be used to simulate a roller coaster ride. These conventional simulators, however, do not have a sufficient range of motion, or simply do not impart an authentic feeling of riding a roller coaster.

Moreover, conventional simulators are as likely as conventional roller coasters to become boring because the "ride" taken by the rider is repetitive.

There are also conventional computer programs which allow a user to design, on a computer, a traversable track. In 1983, Walt Disney Imagineering (the WED Enterprises) provided to EPCOT in Orlando, Fla., a branching videodisc based interactive attraction called "Design a Coaster." The design was started with a slight drop sequence. Guests, using a touchscreen, would select subsequent individual track segments from a menu. The selections would be linked together to form a complete roller coaster track. Some segment selections would be disallowed, for example a loop or a corkscrew segment was not valid as the first selection because there was not sufficient speed developed. An additional drop was required first. Once selected, a segment was removed from the pool of potential selections (e.g., the guest could only have one corkscrew or one loop in the completed track). Once about five selections had been made, the track was completed automatically and the attraction would play a video of a ride on that track. Every possible sequence beginning with the initial segment was pre-recorded on the videodisc. There was a video sequence for the addition and evaluation (e.g., valid vs. invalid) of each segment remaining to be added to each legal string of segments. With all restrictions, the game would actually support only a very few completed tracks (i.e., two), so there were few possible ride sequences recorded on the disc.

In 1995, Apple Computer, Inc. published a computer program called "Gerbils!" which allows a programmer to build a "rodent-coaster" track, and then use a computer monitor to see what it would be like to traverse the track from the view point of a gerbil moving along the track. Similarly, Walt Disney Computer Software, Inc. has published a computer program called "Coaster," which allows a programmer to design a coaster within certain design parameters, and then use a computer monitor to see what it would be like to ride the coaster. These approaches, while interesting from a design perspective, suffer from a lack of thrills. Seeing a moving image on a computer screen is simply not as exciting an experience as seeing, hearing and feeling the ride in real time.

Accordingly, the need exists for an amusement ride which accurately simulates the visual, audible, and physical effects of a roller coaster, and which provides for much greater variation in the ride which can be taken to increase the popularity and useage of the ride.

SUMMARY OF THE INVENTION

In one embodiment, the present invention provides a realistic roller coaster simulator having one or more passenger seats equipped with a safety harness and mounted for rotational movement along at least two axes for simulating the motion of a roller coaster. A motion controller is provided for controlling and coordinating the motion of the passenger seat with a simulation controller which coordinates the simulation of real time virtual reality type audio and visual effects which would be experienced by a passenger on a roller coaster of a predetermined design. A selection controller communicates with a computer storage means which stores data relating to a plurality of predetermined roller coaster designs. On inputting acceptable user information (such as information for billing purposes and/or individual identification information), the passenger is offered a choice of roller coaster designs for a simulated ride. The passenger selects a specific design, which is transferred to the simulation controller. The passenger is secured in the passenger seat. Upon initiation of the simulation, the passenger experiences in real time the visual, motive, audible, and other effects (e.g., heat, wind, etc.) of a real roller coaster ride.

In yet another embodiment, the present invention includes a design station operably linked to the roller coaster simulator which enables a user to design his or her own roller coaster, and then ride it. In this embodiment, the user employs a design station having an input means and a display means to design a roller coaster. Upon inputting acceptable user information (for example, for billing and/or identification), the design station will first offer the user a choice of terrain from predetermined landscape images. Once the terrain has been chosen, the user is given the choice of a plurality of roller coaster segments which can be linked together around the chosen terrain to form a complete roller coaster. The design station contains data representing the three dimensional size and shape of each landscape image and roller coaster segment, and predetermined rules for determining if any selected roller coaster segment can be placed at a selected position on said landscape image and/or joined to a free end of an already placed roller coaster segment. Once the design is completed, a real time, virtual moving image of a ride on the designed roller coaster can be created and displayed to enable the user to determine if the design is acceptable. If acceptable, the design station can be directed by the user or by programmed instructions to automatically save the completed roller coaster design for later retrieval. If the design is not acceptable, the user can change the design by deleting and replacing unsatisfactory

segments and/or by changing the level of thrill. A saved design can be associated with the designer's unique identifying user information, to enable its retrieval for simulation in a roller coaster simulator of the present invention.

Other and further objects, features, advantages and embodiments of the present invention will become apparent to one skilled in the art from reading the Detailed Description of the Invention together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a logic diagram illustrating the primary components of a preferred embodiment of the present invention;

FIG. 2 is a preferred touchscreen layout of the present invention;

FIG. 3 is a diagram illustrating the preferred design components of the present invention;

FIG. 4A is a side view of a simulator of the present invention;

FIG. 4B is a back view of a simulator of the present invention;

FIG. 5 is a cross-sectional side view of a simulator passenger compartment of the present invention;

FIG. 6 is a cross-sectional top view of an alternate simulator passenger compartment of the present invention;

FIG. 7 is a functional block diagram showing a preferred electronic system for a design workstation of the present invention;

FIG. 8 is a functional block diagram showing a preferred electronic system for an operator's console for controlling a simulator station of the present invention;

FIG. 9 is a functional block diagram showing a preferred electronic system for creating the real-time virtual reality type audio and visual effects in a simulator of the present invention;

FIG. 10 is a functional block diagram showing a preferred electronic system for a simulator vehicle of the present invention; and,

FIG. 11 is a functional block diagram showing a preferred electronic system for a user input device for selecting a roller coaster design to be simulated.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. 1, the present invention includes two primary components: one or more design stations 12 for designing a roller coaster, and a simulator station 100 for simulating a ride on a stored roller coaster design.

Design Station

As shown in FIGS. 1 and 3, a Design Area 10 can be provided which includes one or more design stations 12, and a storage device 14. The design stations 1 2 are preferably desktop computers provided with touchscreens which are capable of generating 3D graphics, image processing, and real time video processing. The O2™ line of workstations from Silicon Graphics, Inc., which are based on MIPS R5000 CPUs and offer unified memory architecture, are most preferred. Each design station 12 is electronically coupled preferably via a network as shown in FIG. 7 to a computer memory or storage device 14 which can be used to store completed roller coaster designs. A variety of pre-determined landscape images and roller coaster segments which can be selected by a guest or user during construction of a specific roller coaster design, data representing the three dimensional size and shape of each landscape image and roller coaster segment, and predetermined rules for determining if a first roller coaster segment can be placed at a selected position on said landscape image to start a roller coaster design, and if subsequent roller coaster segments selected by a guest can be joined to a free end of a placed roller coaster segment at a selected position on said landscape image as the guest designs a roller coaster can be stored in memory 14, or, alternatively but less desirably, can be stored in memory associated with each design station 12. The memory device 14 can also be used for storing a program for creating a virtual reality type moving image of a virtual ride on a stored roller coaster design, or data relating to a virtual reality type moving image which was previously created. Alternatively, the roller coaster data could be recorded on a data card carried by the guest.

Associated with the design station is one or more user input devices. For example, for commercial use in a theme park setting, an input device, such as a reader 18, can be used to obtain identifying information from a guest. Reader 18 could be a magnetic card reader (used, for example, in conjunction with an encoded magnetic data card) or an optical scanner (used, for example, in conjunction with a card encoded with a bar code). In addition, reader 18 could also include a radio frequency identification receiver, or biometric reader. Reader 18 could be provided at each design station 12, or alternatively could be provided to control entry to the design area 10 and linked directly to a central park controller. For theme park use, for example, a guest could obtain a data card with unique identifying data for entry to a theme park by paying a requisite entry fee. Alternatively, the guest could pay a sum of money and receive a credit on a debit card. The guest could then swipe his card through a card reader to identify herself or himself to the design station, or a central park computer accessed via a network, which could then determine if the guest is authorized to use the design station (i.e., meets entry requirements, has paid the appropriate entry fee etc.). Where a debit card system is used, the central park computer (not shown) or the design station 12 could reduce the amount remaining on the card by the fee charged for this activity. Assuming all requirements are met, the guest is then able to use a single design station 12 to create and, if desired, save, a new roller coaster design, or edit a stored roller coaster design.

As shown in FIG. 7, design station 12 preferably includes a speaker 21 and a touchscreen 20. Alternatively, a conventional computer monitor could be used in lieu of a touchscreen in combination with a keyboard, mouse, light pen, and/or a voice activated input system.

A preferred touchscreen layout is shown in FIG. 2. In this layout, the central portion of the screen displays a landscape 22 with terrain features on which the roller coaster is to be built. A variety of different landscapes and terrains can be produced and stored for selection by guests, and themed for use in a theme park setting. Thus, it would be possible to theme the landscapes in very different ways (futuristic city, desert, grand canyon, Washington monuments, tropical island, jungle, moon, planet rings, volcanic mountain, underwater world, ice world, wild west, Never Never Land, etc.) as well as vary them by time (grand canyon during time of the dinosaurs; Paris at the time of Napoleon; Ancient Rome of the Caesars; ice age landscape, etc.)

Once a landscape 22 has been selected, the guest may then choose the level of thrill, for example, by selecting when prompted the desired speed (e.g., "fast", "faster," "fastest", or some other scale from a minimum to a maximum relative speed), or some other increments of speed or performance.

The measure of the thrill experienced has two components: vehicular speed and the severity of track convolutions. Adjustments can be made according to a conventional scaling system, for example: 1 being the slowest/mildest (least thrilling) and 5 being the fastest/most convoluted (most thrilling). Thus, the guest preferably can independently control speed and convolutions by touching the screen to indicate an increase or decrease the level.

The design station is most preferably provided with predetermined rules so that the cumulative thrill desired by the guest does not exceed a predetermined level in order to keep guest sickness, due to motion disorientation, to an acceptable level. Thus, for example, factors such as the weight of the guest can be taken into account in controlling the forces imparted by a simulator on the guest. (For example, weight could be determined in advance, by weighing a guest upon entry and encoding this information on a datacard, or on the fly, by providing a means for weighing a seated guest). Likewise, to prevent injury to guests, the design station can alter segments as necessary. For example, in an event where a guest chooses high speed and a loop, the design station can increase the diameter of the loop segment, since a tight loop at high speed might injure a guest if accurately simulated. In particular, it is preferred to limit the rate at which acceleration on a riding guest is changed. Not only is this a function of the finite performance of a physical motion base, but it is also a matter of guest comfort. As discovered in the earliest days of railroads, the sudden onset of a lateral acceleration (e.g., a straight track which transitions to a curve too abruptly) tends to induce discomfort in passengers (if it does not knock them over). For this reason, both within a track segment and at the joint where two track segments meet, it is desirable to limit the rate of change of curvature and discontinuities in the direction of travel along the track (e.g., no angles which would correspond to a point where the radius of curvature is zero). Situations where this recommendation would be violated would include a simulation of riding down stairs, or hitting a wall. In such a case, the limits of the simulator will likely be the moderating factor.

With the level of thrill set, the guest may select a starting point on the landscape **22**, or preferably the design station can require the use of a predefined starting point **23**. The guest can then choose a track segment by touching one of the track segment buttons **24** or icons **24'** displayed on the screen. This choice will be analyzed by the workstation using predetermined rules accessible by the design station **12** to determine if the selected track segment violates any of the rules (e.g., tracks cannot penetrate the ground surface, tracks don't penetrate each other, track can be looping or open, overall progress is made through the landscape). As data representative of the size and shape of both the terrain and the track segments are accessible by the design station **12**, these rules can be easily and quickly applied.

Assuming the rules are not violated, the guest is informed of the acceptability of his choice when the track segment **25** appears in the desired start location. A track remaining indicator **26** shows the amount of track remaining. The guest then selects another track segment to be linked to a free end of the first placed track segment by, again, touching the track segment buttons **24** or icons **24'** corresponding to the desired segment. Again, the system compares the choice to the environment (the terrain and previous track segment) to determine if the new track segment violates the rules. If not, the next track segment **25'** appears, connected at the desired end of the first track segment **25**. If the rules are violated, a message appears informing the guest that a different choice is required. Track segment buttons **24** and icons **24'** will vary in severity from low (e.g., straight away, simple s-curves, and simple hills) to high (e.g., corkscrews, inverted loops). The more thrilling icons can be deactivated (to prevent their selection) where the guest chooses a low thrill level. Alternatively, selecting a high thrill level could produce additional icons **24'** on the screen or light additional buttons **24** on the panel for selection by the guest. Alternatively, guests could be permitted a great deal more detailed control over the shape, size and severity of the track (e.g., the height and diameter of a loop). However, the track segment selection technique described above is preferred because it allows a much faster design time.

Specific guest communication icons **28** can also be provided on the touchscreen. The present invention preferably provides a "Help" icon (with which the guest can receive instructions and helpful information on designing a roller coaster using the design station); an "Undo" icon for removing a track segment if the guest changes his or her mind; and a "Done" icon for informing the design station that the design of the roller coaster is complete. Both the track segment icons and/or the guest communication icons could, alternatively, be provided as mechanical switches such as, for example, pushbutton switches mounted on or adjacent the touchscreen.

Alternatively, but less preferably, a guest could create a track using commercially available 3-D equipment. For example, the guest would be provided a pair of 3-D glasses capable of producing a 3-D image in conjunction with the screen. Using a mouse that can read 3-D position in space, the guest could draw the desired track on the 3-D image of the terrain. In an actual test of this concept, the track appears to be extruded out of the mouse like a trail of toothpaste from a tube. In this way, the guest can directly draw loops and corkscrews, curves and humps in whatever way is desired. While visually attractive, this embodiment requires time for the untrained guest to adjust to the effective use of the equipment, and for that reason is not preferred in a commercial environment.

Once a specific roller coaster design is complete, it is preferably saved with the guest's unique identifying data for recall later. Preferably, the guest is prompted to name his or her coaster to differentiate among potentially multiple designs. For speed, the name is preferably comprised of a selection from two groups of words (for example, one group of adjectives and one group of nouns). Thus, for example, the first group of words could include terms like "Screamin', Cosmic, Astro, Cyber, Wily, Jolly, Turbo, Atomic, and Way Cool;" and the second group of words could include terms like "Shredder, Coaster, Express, Trolly, Riot, Rocket, Chariot, O-Matic, and Banshee."

Preferably, the guest is able to preview a ride on the saved roller coaster design, either at the workstation **12** (via the touchscreen) or on a separate previewing monitor or screen (not shown). Preferably, this can occur incrementally with the addition of each track segment. A computer program run on a simulation computer (described in more detail below under the Simulation Station) could also be used to convert the design to a three-dimensional, virtual reality type moving image in real time.

Optionally, on completion, if the design is not all that the guest intended, the guest may modify the design using the undo icon. Once the design is what the guest intended, the guest can then, if desired, proceed to the simulation station **100**.

The Simulation Station

As shown in FIG. 1, the simulation station includes at least one simulator ride vehicle **120** which is preferably controlled by a simulation computer/controller **110** through a motion or ride controller **118**.

Selection controller **112** can be any computer capable of retrieving the data stored in storage device **14**. The guest preferably uses selection controller **112** to choose from among several designs the guest has created. The choices may also include several "canned" designs, which the guest may choose if they appear more attractive, or if the guest has not designed a track. A guest identifies himself using input device **18'** (for example, by passing a magnetic data card through a magnetic card reader). Once a design has been selected at the selction controller **112**, and simulation controller **110** is in a receptive mode (as opposed to being fully involved in an on-going simulation), the track design data is transferred to the simulation controller **110**.

A video controller **115**, which is capable of producing real time, 3-D virtual reality type imagery, is preferably provided. In the preferred embodiment, the video controller **115** and simulation controller **110** are provided by the same machine. For this purpose, the SiliconGraphics, Inc. Onyx2 Infinite Reality™ deskside system is preferred. This system includes preferably two (to limit expenses) but may include four 4 MB cache MIPS R10000 processors, 64 MB to 2 GB of memory (preferably 128 MB), a single graphics pipeline with at least one, but preferably two InfiniteReality™ Raster Managers. This system is capable of producing several million textured Z buttered polygons/sec, and can generate over 194 million textured, anti-aliased pixels per second. 16 MB of texture memory is preferably provided, though more is available at increased expense. Because of the cost of this hardware, it is strongly preferred that a video display manager be capable of displaying on at least 8 monitors simultaneously be employed. This allows for the single expensive image generator to drive 4 simulators at high resolution, as well as 4 associated monitors for nonriding guests to view the ongoing action. Video output of at least about 30 Hz is required; however, about 60 Hz S.V.G.A. at 800×600 resolution is preferred. Typical electrical power requirements disclosed in the Onyx-2 technical specifications for this system are: 110 to 220 VAC; 50 to 60 Hz; 2,500 watts; 8,500 BTU/hr heat dissipation; NEMA5-20, 110 VAC @20A; NEMA6-20, 208 VAC @20A.

In creating and replaying the design, the simulation computer receives the information in the storage device **14** from selection controller **112**. System RAM of controllers **110** and **115** are preferably optimized by making use of database and texture paging. At run-time, the application can preload all show components. Then it can "unstuff" portions of the database that are not in use. Unstuffing consists of compressing large data components and then removing the memory-consuming original details while leaving the object data structure skeleton in place. Then, when the object is needed, it can be "stuffed": it need not be re-created, but can simply be fleshed out to its original form by expanding the compressed contents and attaching them to the skeleton. This has the advantage of avoiding processor hungry runtime constructors and memory allocation calls and also lets the "unstuffed" objects remain valid to the system so they can be paged asynchronously with no direct synchronization required to the real-time visuals.

An operator's console **114** can be provided for the use of theme park operators for operation and safety purposes and to enable the operator to, for example, start and stop the simulator **120**, and authorize access to the simulator **120** for loading and unloading passengers. As shown in FIG. **8**, an operator's console can be provided with a touch screen monitor for ease of control, a network link which can be used for a variety of purposes, including retrieving data from multiple controllers, such as, for example, **110**, **115**, **118**, under its management, and a PC which can be used control and monitor systems on-board (e.g., video projectors) and in the queue (or "preshow") area where guests wait before boarding the simulator.

As shown in FIG. **11**, selection controller **112**, which preferably includes a data reader **18'**, can be provided for obtaining the guest's unique identification data and status. Most preferably, the guest is then given a choice, and may make a selection from a menu of roller coaster designs which preferably includes any designs created by the guest and saved on storage device **14**, and may also include one or more other roller coaster designs available for selection by the guest (for example, the theme park may choose to provide designs of famous roller coasters). As noted above, a touchscreen device is preferred for displaying choices and obtaining the guest's selection; however, other conventional devices such as, for example, a conventional monitor in combination with a keyboard, mouse, light pen, and/or voice activated system may also be used.

Alternatively, a data reader (not shown) could be used to input the guest data, a screen or monitor used to display the roller coaster design choices on operator console **114**. The operator could then input the guest's choice via the operator input device **114**. If the roller coaster data is recorded on a data card carried by the guest, reader **18'** could also provide the roller coaster data to the selection controller **112**.

Simulator **120** can be any conventional simulator capable of imparting realistic roller coaster motions to at least one passenger. Examples of such conventional simulators are disclosed in U.S. Pat. Nos. 4,710,128; 5,353,242; 5,021,982; 5,507,647; and 5,388,991, which are incorporated herein by reference for all purposes.

A simple form of simulator is shown in FIGS. **4A** and **4B**. In this embodiment, a passenger sits in a passenger seat **122** which includes a seat harness **124** for restraining the passenger in passenger seat **122**. A virtual reality type helmet **126**, which projects image and sound to the passenger and is in communication with the video and audio controllers **115** and **116**, can be donned by the passenger. Alternatively, the passenger could don virtual reality goggles and earphones.

As shown in FIGS. **4A** and **4B**, realistic motion can be imparted to the passenger seat **122** by rotation about one or more of three axes: a pitch axis **128**, a roll axis **130**, and a yaw axis **132**. A motor drive **134** for rotating the passenger seat **122** about the pitch axis, a motor drive **136** for rotating the passenger seat about the roll axis, and a motor drive **137** for rotating the passenger seat about the yaw axis can all be provided, and could be linked to the ride controller **118** for control and coordination with the simulation controller **110**. In the preferred embodiment, the passenger seat is rotated at least about the pitch and roll axes. For some elements, such as a corkscrew, yaw may be added to provide a more realistic simulation. Most preferably, to provide the most realistic simulation, rotation about the pitch and roll axes of rotation is a full 360 degrees and capable of continuous motion, and rotation about the yaw axis is preferably 90 degrees +/- for full simulation. In positioning passenger seats with relation to the pitch, roll, and yaw axis, the centerline locations for passengers are preferably at or above the heartline, to provide the most realistic feeling simulation.

Ride controller **118** can accept from simulation controller **110** realtime data indicative of the acceleration on the virtual coaster car travelling the track at the point where the current video is being generated and displayed on screen **142**. This process causes the simulator to take on an aspect which best simulates the accelerations that would be experienced on an actual coaster. The exact algorithm would depend upon the degrees of freedom and particulars of the motion base. Alternatively, and preferably, motion controller **118** contains prerecorded motion base control sequences constructed by hand by motion experts for each potential track segment and traversal speed combination. At the beginning of the simulation, the set of track segments is relayed along with traversal times to the motion controller **118**. The simulation controller **110** begins the simulation with a start signal. On reception of the start signal, the motion controller **118** starts playing the prearranged sequence of motion while, in synchrony, the video and audio controllers (**115** & **116**) generate their respective performances under control of the simulation controller **110**. Alternatively, video and audio might be generated by this same prearrangement scheme (e.g., with a videodisc player being told which segments and in what order to play).

More preferably, as shown in FIGS. **5** and **6**, the simulator **120** includes a passenger compartment **138** mounted for 360 degree rotation along at least the pitch axis **128** and the roll axis **130**. The preferred ordering of the axes in this preferred two axis system is: roll axis innermost and pitch axis outermost. A passenger seat **122** provided with a seat harness **124** and/or other conventional restraining devices can be mounted securely to the floor **140** of passenger compartment **138**. Most preferably, two passenger seats, as shown in FIG. **6**, are provided.

A viewing screen **142** can be provided for displaying the real time, three dimensional virtual reality type image of the simulated roller coaster ride generated by video controller **115**. The viewing screen **142** can be a front or rear projection type television set. Most preferably, the image is front projected preferably by an LCD video projector **144** mounted behind the passenger. The projector **144** may project directly to the viewing screen **142** if desirable; however, if necessary to increase the image size in a restricted passenger compartment by increasing the effective distance between the projector and the screen (referred to as the "throw" distance), the projector may project the image first to a mirror **146** which reflects the image to the screen **142**.

Speakers **148** can be mounted in appropriate locations in the passenger compartment for broadcasting realistic sound to accompany the projected image. Most preferably, stereo speakers (not shown) are located in the seat headrest. A low frequency transducer or subwoofer **150**, can be mounted in or closely adjacent to the passenger seat **122** to produce realistic vibrations to be sensed by the passenger in association with the projected image.

A door or hatchway **152** can be provided to enable a passenger to enter and leave the simulator vehicle passenger compartment **138**. A locking device **154** is preferably provided to securely lock the hatchway in a closed position. Finally, a ventilation system (not shown) is most preferably included for providing fresh air changes in the passenger compartment **138**. Such fresh air changes are important for reducing the possibility of motion sickness.

For safety reasons, the simulator vehicle is preferably contained in a safety enclosure (not shown) which is also provided with a locking doors. This safety enclosure prevents operator personnel or passengers waiting in the queueing area, from coming in contact with the moving simulator vehicle. Most preferably, sensors are provided so that entry into this enclosure during operation will cause an emergency stop of the simulator **120**.

As shown in FIG. **10**, motion of the simulator vehicle can be controlled by the motion controller **118**—preferably an off-board PC which, for safety purposes, is preferably directly linked to the motors responsible for generating the specific movements, panic STOP buttons, harness switches, and door latches. Alternatively, but at greater risk of software failure, the function of the motion controller **118** can be performed by a processor that is multitasking other functions such as those performed by video controller **115**, audio controller **116**, and simulator controller **110**. Sensors can be provided as desired to verify that the passenger is in the passenger seat, the restraining harnesses are engaged and locked, and each hatchway or door is closed and locked. Surveillance equipment, such as the closed circuit television camera **145** shown in FIGS. **5**, **6**, and **9**, can be mounted inside the passenger compartment and linked to the operator's console or to a separate surveillance console for observation purposes, and to enable the operator to intervene in the event a passenger becomes ill during the simulation. Finally, emergency stop buttons can be provided both inside the simulator passenger compartment (for use by a passenger) or in the operator area for emergency use by the operation personnel.

To use a preferred simulator station of the present invention, the guest enters a queueing area which leads to a loading zone. The queueing area may be provided with special lighting effects, theme art, and/or monitors or other video displays projecting actual or simulated visual and audio effects. When the guest arrives in the loading area, the guest provides his or her identifying information to the system using input device **18'** (for example, by swiping a magnetic card through the card reader) and chooses a roller coaster design from the choices obtained from storage device **14** and displayed on a screen by selection controller **112**. The operator optionally confirms the guest's choice, opens the safety enclosure door, and opens the hatchway **152** into the simulator vehicle **120** passenger compartment **138**. The guest enters the simulator safety enclosure and may be asked to empty his or her pockets into a tray or other suitable receptacle, until the ride is over. More preferably, however, the seat **122** and restraint **124** provide a sufficiently snug embrace that pockets are not disposed to disgorge their contents even when the passenger compartment is inverted.

The guest enters the simulator passenger compartment **138** and sits in a passenger seat **122**. The passenger harness **124** is secured about the guest, and the secured condition of the harness is preferably verified by the operator or an operator's assistant. The operator, having preferably performed a final safety inspection for loose articles and the like in the passenger compartment, closes and locks the simulator hatchway **152**, and exits the simulator safety enclosure, closing and locking the safety enclosure door. With the guest secured and ready for the ride, the operator begins the program either from the operator console **114**, or, preferably, from a conveniently located but secure switch. At this time it is possible, and preferred in order to minimize the time in queue, for the next guest to use the selection controller in preparation for their ride.

As the ride is in progress, special lighting effects may be provided in the simulator passenger compartment to heighten the experience, or outside of the simulator as a visual indicator that the simulator is in operation. Other

realistic effects may be added, for example: an air stream may be directed at the guest's face to simulate wind, the air stream may be heated if the simulated environment is hot, the air stream may be chilled if the simulated environment is cold, or water droplets may be sprayed on the guest if the simulated environment is wet. Should the guest become ill or too disoriented to continue the ride, an emergency STOP button is provided which can be used to stop the ride. Once the ride ends, and the simulator has stopped moving completely, the operator opens the door to the safety enclosure, opens the simulator hatchway, and releases the passenger harnesses. The guest exits the simulator, and retrieves his pocket contents in the safety enclosure before exiting the safety enclosure.

One skilled in the art will recognize at once that it would be possible to construct the present invention from a variety of materials and in a variety of different ways. While the preferred embodiments have been described in detail, and shown in the accompanying drawings, it will be evident that various further modification are possible without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A roller coaster simulator comprising:

a design station which can be used by a plurality of guests to design a simulated roller coaster, said design station linked to a computer shared by other similar design stations having access to pre-determined landscape images and roller coaster segments which can be selected by a guest, data representing the three dimensional size and shape of each landscape image and roller coaster segment, and predetermined rules for determining if a first roller coaster segment can be placed at a selected position on said landscape image to start a roller coaster design and if subsequent roller coaster segments selected by the guest can be joined to a free end of a placed roller coaster segment at a selected position on said landscape image as the guest designs a roller coaster, said design station including means for associating guest identification data with each roller coaster design created on said design station;

storage means shared by a plurality of design stations for storing and accessing data related to each roller coaster design completed by said guest at the design station;

a simulator vehicle for simulating the motion of a roller coaster, and including a passenger compartment, at least one passenger seat mounted in said passenger compartment, a safety harness for securing said guest in said passenger seat, and a means for moving said passenger compartment to simulate the motion of a roller coaster;

a means for creating a moving picture of a virtual ride of a selected roller coaster design stored in said storage means from the perspective of said guest when seated in said passenger seat, said means for creating a moving picture mounted outside said simulator vehicle;

a projector mounted in said simulator vehicle for displaying said moving picture to a passenger, said projector connected to said means for creating a moving picture by a cable; and

a first controller means for accessing said data stored in said storage means and for using said data to control and synchronize the motion of the passenger compartment with the moving picture to create a realistic simulation of said selected roller coaster design.

2. The roller coaster simulator of claim 1 additionally comprising a sound system means for generating or replaying realistic sounds in synchronization with said moving picture and said means for moving said passenger compartment during a simulation.

3. The roller coaster simulator of claim 2 wherein said sound system is controlled by an audio controller which is operably linked to said first controller.

4. The roller coaster simulator of claim 2 additionally including a sound controller for controlling said sound system, said sound controller in communication with said first controller.

5. The roller coaster simulator of claim 1 additionally comprising a means mounted in said passenger compartment for generating vibrations to be sensed by the guest.

6. The roller coaster simulator of claim 5 wherein said means for generating vibrations is a subwoofer associated with said passenger seat.

7. The roller coaster simulator of claim 6 wherein said subwoofer is controlled by an audio controller which is operably linked to said first controller.

8. The roller coaster simulator of claim 1 additionally including guest input means for providing guest information and selections to the design station and first controller.

9. The roller coaster simulator of claim 8 wherein said guest input means is selected from the group consisting of magnetic card readers, optical card readers, radio frequency identification receivers, biometric readers, touchscreens, mouses, keyboards, light pens, and voice activated input devices.

10. The roller coaster simulator of claim 1 wherein said passenger compartment includes a lockable hatchway.

11. The roller coaster of claim 10 additionally including a safety interlock means to prevent initiation of a simulation unless said hatchway is closed and locked, and said guest is seated in said seat with said safety harness engaged.

12. The roller coaster simulator of claim 1 wherein said passenger compartment is pivotally mounted to rotate about 360 degrees about at least two axes.

13. The roller coaster simulator of claim 12 wherein said two axes are a roll axis and a pitch axis.

14. The roller coaster simulator of claim 1 wherein said design station includes a design display means operably linked to the computer for displaying a selected landscape image, roller coaster segments selected by a guest during the design process, and communications from said design station to the guest.

15. The roller coaster simulator of claim 14 wherein said display means is selected from the group consisting of touchscreens, monitors, and printers.

16. The roller coaster simulator of claim 1 wherein said means for creating and displaying a moving picture creates a virtual reality type real time image.

17. The roller coaster simulator of claim 1 wherein said means for moving said passenger compartment includes at least one motor controlled by said first controller.

18. The roller coaster simulator of claim 1 wherein said means for moving the passenger compartment includes at least one motor controlled by a ride controller in communication with said first controller.

19. The roller coaster simulator of claim 1 wherein said projector is a video projector.

20. The roller coaster of claim 19 additionally including a video controller for controlling said video projector, said video controller in communication with said first controller.

21. A roller coaster simulator comprising:

a passenger seat with a safety harness, said passenger seat mounted for movement by a means for imparting the motion of a roller coaster to said passenger seat;

a means for creating a real-time, virtual moving image of a roller coaster design retrieved from a storage means and selected for replay by a passenger before said passenger is secured by said safety harness to said passenger seat;

a controller means for controlling and coordinating the means for imparting motion and the means for creating said real-time, virtual moving image of said roller coaster design during replay of a selected roller coaster design without any input from the passenger;

a video display means for displaying said virtual moving image to said passenger, said video display means mounted for synchronous movement with said passenger seat and connected to said means for creating a real-time virtual moving image by a cable.

22. The roller coaster simulator of claim **21** additionally comprising a display device associated with said controller means for displaying predetermined roller coaster designs for selection by said passenger prior to replay of said selected design.

23. The roller coaster simulator of claim **21** additionally comprising a passenger input device for inputting said passenger's selection of a roller coaster design stored in said storage means to the controller means prior to replay of said selected design.

24. The roller coaster simulator of claim **21** wherein at least one of said roller coaster designs retrieved from said storage means was created by said passenger.

25. The roller coaster simulator of claim **24** wherein said passenger created said roller coaster design using a design computer operably linked to a passenger input device, a design display device, and means for storing and accessing pre-determined landscape images and roller coaster segments which can be selected by the passenger for joining to the free end of other roller coaster segments to form a completed roller coaster design, along with data representing the three dimensional size and shape of each landscape image and roller coaster segment and rules for determining if specific selected roller coaster segments selected by a passenger can be joined to a free end of another roller coaster segment at a selected position on said landscape image.

26. The roller coaster simulator of claim **21** wherein said video display means is selected from the group consisting of: helmet mounted virtual reality displays, goggle mounted virtual reality displays, front or rear projection television sets, projectors and screens.

27. The roller coaster simulator of claim **21** additionally including audio means associated with said video display means for replaying or generating realistic sounds associated with roller coaster motion as simulated.

28. The roller coaster simulator of claim **27** additionally including means associated with said passenger seat for imparting a vibration to said passenger seat to simulate vibrations sensed during a roller coaster ride over segments such as those being simulated.

29. The roller coaster simulator of claim **21** wherein said passenger seat is mounted to rotate 360 degrees along at least two axes.

30. The roller coaster simulator of claim **29** wherein said two axes comprise a roll axis and a pitch axis.

31. A roller coaster simulator comprising:

a design station including a computer having access to pre-determined landscape images and roller coaster segments which can be selected by a guest, data representing the three dimensional size and shape of each landscape image and roller coaster segment, and predetermined rules for determining if a first roller coaster segment can be placed at a selected position on said landscape image to start a roller coaster design and if subsequent roller coaster segments selected by the guest can be joined to a free end of a placed roller coaster segment at a selected position on said landscape image as the guest designs a roller coaster, and a display means operably linked to said computer for displaying a selected landscape image, roller coaster segments, and communications from the design station;

storage means, operably linked to said design station and a plurality of other like design stations, for storing and accessing completed roller coaster designs transmitted from said design station;

a simulator vehicle for simulating the motion of a roller coaster, and including a passenger seat, means for restraining a passenger in said passenger seat, and a means for moving said passenger seat;

a means for creating a real-time, virtual reality type moving picture of a virtual ride of a selected roller coaster design stored in said storage means, said selected roller coaster design chosen in advance for replay to the passenger from a plurality of roller coaster designs stored in said storage means;

a display means mounted inside said simulator vehicle for displaying said moving picture to a passenger, said display means linked to said means for creating a real-time, virtual reality type moving picture of a virtual ride;

a first controller means for controlling and coordinating the motion of the passenger seat to the motion visually depicted by said display means associated with said selected roller coaster design, said first controller means operably linked to said means for creating a real-time, virtual reality type moving picture; and,

guest input means for providing passenger identification and selections to the design station and first controller.

32. The roller coaster simulator of claim **31** additionally comprising a sound system means for generating or replaying realistic sounds in synchronization with said means for creating a real-time, virtual reality type moving picture.

33. The roller coaster simulator of claim **31** additionally comprising a means associated with said simulator vehicle for generating vibrations to be sensed by the guest.

34. The roller coaster simulator of claim **33** wherein said means for generating vibrations is a subwoofer associated with said passenger seat.

35. The roller coaster simulator of claim **31** wherein said guest input means is selected from the group consisting of magnetic card readers, optical card readers, radio frequency identification receivers, biometric readers, touchscreens, mouses, keyboards, light pens, and voice activated devices.

36. The roller coaster simulator of claim **31** wherein said passenger seat is pivotally mounted to rotate about 360 degrees about at least two axes.

37. The roller coaster simulator of claim **36** wherein said two axes are a roll axis and a pitch axis.

38. The roller coaster simulator of claim **31** wherein said means for displaying said moving picture is selected from the group consisting of virtual reality helmets, virtual reality goggles, rear or front projection television and projectors and screen.

39. The roller coaster simulator of claim **31** wherein said means for moving said passenger seat includes at least one motor.

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